

**MORTALITY AMONG EMPLOYEES OF ATLAS SPECIALTY STEELS
WELLAND, ONTARIO**

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INTRODUCTION

In November 1987, the Minister of Labour received a letter from the Health and Safety Coordinator of the United Steel Workers of America who expressed concern about a perceived high rate of lung cancer among employees of the Sherman Avenue plant of Slater Steels in Hamilton. The Health and Safety Committee voiced particular anxiety about the occurrence of cancer in the Melt Shop area of the plant and it was agreed that the Ministry of Labour would undertake an exploratory study to determine whether the cancer experience of Slater Steels employees was indeed different from the Ontario average. The most rapid method of reaching an answer was to analyze those deaths which could be identified from Company files, and the major question to be addressed was whether men who had worked in the Melt Shop at Slater Steels had experienced an increased risk of lung cancer.

The study population comprised 131 men. Twenty-three men had worked in the Melt Shop while 108 had not. The proportion of deaths from cancer was less than the Ontario average among men without Melt Shop exposures, while there was a small excess (9 observed, 5.8 expected), attributable to a 3-fold increase in lung cancer mortality, among men who had worked in the Melt Shop.

Jobs held by Melt Shop employees who died of lung cancer included Pitman, Crane Operator, Ladleman, Furnaceman, Tundish Conditioner, and Mold Inspector. A number of men had held several different jobs and an attempt was made to allow for this by mathematical modelling. All 3 of the men who had worked as Pitmen died from lung cancer, and the Pitman job remained strongly associated with lung cancer risk ($P < 0.001$) when the other jobs were taken into account. The Crane Operator job remained moderately associated with lung cancer risk ($P < 0.1$), but neither the Furnaceman nor Ladleman jobs

were significantly associated with risk when account was taken of the other jobs performed.

Extensive environmental sampling was performed at the plant by the Health and Safety Support Services Branch of the Ministry of Labour. Although elevated levels of the carcinogenic metal, arsenic, were detected in a number of samples, no definitive conclusions could be drawn about a cause for the increased risk of lung cancer.

At the conclusion of the Slater investigation, 2 explanations for the lung cancer cluster in the Melt Shop were plausible. Firstly, the cluster may have been a statistical fluke, unrelated to occupational exposures. Alternatively, occupational factors may have played a role. As is usually the case with epidemiologic investigations, it was not possible to decide between these alternatives on the basis of the initial study, and it was decided to seek additional information by performing a similar investigation in another plant. A list of Electric Arc steelmaking operations was compiled, and the Atlas Specialty Steels plant in Welland was the obvious candidate for further study because of its long history and the large size of its workforce. Representatives of the Company were very helpful following a request for information and this report presents the results of the analysis of mortality among Atlas Steels employees.

NARRATIVE REPORT OF THE STUDY FINDINGS

This section of the report presents a narrative discussion of the study and its findings. Details of the methodology and analysis, as well as extensive tables of results, may be found in the Technical Report section. A description of the plant, taken from a publication written by a plant engineer, may be found in the Appendix.

The study design is similar to the one used at Slater Steels. Ms Lee Hannah, Co-ordinator of Occupational Health, and her colleagues in the Pension Department provided a list of deaths among pensioners and active employees, as well as job histories for the deceased workers. The aim of the analysis was to compare the proportion of deaths from lung cancer among Atlas employees with the Ontario average, as well as to make internal comparisons among the various Departments at Atlas.

Causes of death were determined for 393 men, but portions of the work history were missing for 25. These men were excluded from the analyses which utilized job data, leaving a total of 368 former employees for the analysis of mortality by Department.

Table 10A shows the mortality pattern among the 393 Atlas employees in comparison with the Ontario average. Half of the workers died from circulatory diseases, which was the same proportion as the Ontario average. Thirty percent of the deaths were from cancer, slightly higher than the Ontario average of 27%. The increase in cancer mortality was attributable to deaths from respiratory cancers (43 deaths, 38 expected), cancers of the blood and lymphatic system (17 deaths, 9 expected), and prostate cancer (13 observed, 9 expected). The increased rate of death from prostate cancer was not "statistically significant" and analysis showed no association between blood and lymph cancers and employment in any particular Departments. It is concluded that the apparent increases in mortality from the blood and prostatic cancers is

probably not related to employment factors and most likely reflect a statistical fluke.

The major focus in this study was the risk of lung cancer in the Melting Department. Since cigarette smoking is the leading cause of lung cancer in Ontario, it is important to be able to determine whether any differences in lung cancer risk between Departments are due simply to differences in the smoking patterns of the workers in the various work areas. Information about the smoking habits of the workers was sought by Ms Hannah in the files of the Medical Department and from informants who knew the workers. Information about 236 men, obtained during routine visits to the Medical Department, was found in the medical files. For an additional 39 men (6 lung cancer victims and 33 controls), information about smoking was obtained from informants during June and July, 1989. In all, information was available for 275(70%) of the study population of 393 men. Sixty-seven(24%) of the 275 men were non-smokers and 208(76%) were cigarette smokers.

Table 9 shows the relationship between cigarette smoking and lung cancer risk among Atlas employees. Twenty-six(12.5%) of 208 cigarette smokers died from lung cancer, compared to 3(4%) of 67 non cigarette smokers. The age-adjusted risk of lung cancer among cigarette smokers was 2.8 times that of non-smokers. The lower portion of the Table shows that there was a relationship between the number of cigarettes smoked and lung cancer risk.

Turning to an examination of the various Departments, Table 11 shows the lung cancer mortality pattern among men who worked for 2 years or more in any of 19 Departments. Lung cancer rates were increased in some Departments and diminished in others. In the Melting Department, there were 9 deaths from lung cancer, compared to the Ontario average of 5.7 among 55 men of these ages.

Motivated by the lung cancer cluster in the Pit area at Slater Steels, Table 12 focusses on the Pouring Pit area of

the Melting Department at Atlas. The 2-year minimum employment restriction was eliminated for this analysis, and, among 264 men who had never worked in the Melting Department, 9.1% of deaths (which is the Ontario average) were due to lung cancer; among 74 men who had ever worked in the Melting Department, but never in the Pit area, 9.5% of deaths (which is again the Ontario average for men of these ages) were due to lung cancer; among the 30 men who had ever had a job (Pitman, Ladleman, Steel Pourer) in the Pit area, 27% of deaths were due to lung cancer, a rate 2.71 times the Ontario average. The excess lung cancer mortality among the Pit workers is statistically significant. We thus have confirmation of the findings at Slater Steels of an increased lung cancer risk among Pouring Pit workers. There is no evidence of increased lung cancer risk among men working at other Melting Department jobs. Table 19B shows that the elevated risk among Pouring Pit workers persists even after adjustment for smoking habits, indicating that the increase is not an artefact due solely to heavier smoking among Pit workers.

There is generally a substantial time interval between exposure to a cancer-causing agent and development of the disease. This fact has important implications for current workers, since risks being observed now could reflect exposure conditions of many years ago, conditions which might no longer exist. An analysis was undertaken to determine when the exposures most associated with death from lung cancer took place, and the results indicated that it was exposures occurring 18 to 29 years before death that were best able to predict which Pitworkers would develop cancer. Dose-response analysis subsequently found that the longer the time employed as a Pitworker in this 11-year "Time Window", the greater the risk of lung cancer (Figure 4).

For the men in the study population this 18 to 29 year "Time Window" corresponds to Pouring Pit employment during the 1950s and early 1960s. This finding might have 2 important

interpretations, apart from statistical chance. Firstly, it might mean that certain materials or processes were in use between 1950 and 1962 that are associated with the subsequent development of lung cancer. Secondly, this result might reflect the operation of biological processes. On the one hand, it may be that it takes at least 15 years or more for hazardous exposures to result in death from lung cancer; on the other hand, tissues damaged by toxic agents many years before might be repaired or discarded, so that if a cancer has not appeared by 30 or so years after exposure, there might be a very small chance of its ever appearing.

Because of the time lag, determination of what agent or agents might have been responsible for the elevated lung cancer risk in the Pouring Pit areas requires an investigation into historical practices at Atlas and Slater because of changes in the materials used in the pouring areas. These inquiries are in progress.

There are no environmental measurements from the earlier era. Current air sampling for a wide variety of toxic agents in the Melting Department at Atlas finds concentrations of hazardous materials to be within their suggested limits. It was found that, for those chemical substances measured, there were essentially no differences in the exposures of men working in the Pit area and in other workplaces in the Melting Department. Although it is possible that unmeasured hazardous agents might be present, this finding would suggest that current pouring pit workers are not at higher risk than their fellow workers.

Environmental assessment is thus unable to find evidence that current conditions in the Pit area place workers at increased risk of lung cancer, but it is reasonable to presume that surviving men who worked in the Pit area before the mid-1960s remain at increased risk of lung cancer. The best measure to decrease their risk would be to advise any cigarette smokers among them to quit smoking. It is known that

cigarette smoking increases the risk of lung cancer caused by a variety of occupational carcinogens, including asbestos and radon. It is also believed that smoking cessation leads to a lessening of risk. It is thus strongly recommended that all men who worked in the Pouring area be encouraged to quit smoking.

TECHNICAL REPORT

STUDY DESIGN and METHODS

The study design is similar to the one used at Slater Steels. The Company provided a list of deaths among pensioners and active employees, drawn from the records of the Medical and Pension Departments. The aim of the analysis was to compare the proportion of deaths from lung cancer among Atlas employees with the Ontario average, as well as to make internal comparisons among the various Departments at Atlas.

I. Data Collection and Coding

Elisabeth Hannah, Co-Ordinator of Occupational Health at Atlas Steels, kindly agreed to make available copies of insurance death claims from her files as well as copies of the work histories of deceased employees from the Pension Department files. Death certificates, with the officially coded causes of death, were sought at the offices of the Ontario Registrar General. Three men had lung cancer mentioned on their death certificates as a contributing cause of death, but the deaths were officially coded to other causes. The official code was used in all comparisons with Ontario men, but the cause was taken to be lung cancer for comparisons within the Atlas population. One of these 3 men had worked in the Melting Department for more than 2 years, but none had been employed as Pitworkers.

Identifying and occupational data for each subject were entered into a personal computer database. Edit checks were performed to identify and correct errors. Departmental job assignments were coded for each worker, with the dates of entry and termination in each Department. In addition, for every man who had worked in the Melting Department, each individual job was coded, and consistency was verified by checking that the

sum of the times spent in individual jobs was the same as the total time spent in the Melting Department, as computed from the Departmental coding. The list of Departments coded is given in Table 1, and the list of Melting Department jobs is given in Table 2. The job titles for a number of jobs changed over the years, and titles referring to the same, or similar jobs, were consolidated following discussions with Mr. Mike Smalyga, Superintendent of Steelmaking.

When computing the length of time each man had spent in the various Departments or jobs, calculation was truncated at a date 5 years before the death of the worker, with the rationale that any exposure less than 5 years before death was unlikely to have contributed to the development of a malignancy.

II. Comparisons With Mortality in the Ontario Population

The proportions of deaths from various causes in the Atlas population were compared with the proportions in the general male population of Ontario, taking account of the workers' ages and years of death. Computations were done using the Man Years computer program⁽¹⁾. The statistical significance of differences between the proportions observed and expected was assessed using the Poisson distribution, for expected deaths less than 100, and the Chi-Square Distribution when the number of deaths expected exceeded 100. One-tailed tests were used in comparisons involving lung cancer, because of the a priori hypothesis that lung cancer rates would be increased. Two-tailed tests are used elsewhere, unless otherwise indicated. P-values of 0.05 or less are statistically significant.

III. Internal Mortality Comparisons

Conceptually, this analysis can be regarded as a case-control study drawn from an underlying population of Atlas

retirees and active employees. The cases are those men who died of lung cancer during the observation period and the controls are sampled from among the men free of lung cancer. In this instance, the sampling strategy selects as controls men who died from causes other than lung cancer during the observation period. In order for interdepartmental comparisons of lung cancer risk to be valid, it must be assumed that, apart from lung cancer, there is no association between the risk of death from major causes and employment in any Department. If, for example, employment in the Melting Department protected workers against death from heart disease, but Melting Department workers developed lung cancer at a normal rate, then the proportion of deaths from lung cancer would appear to be elevated in the Melting Department and one would incorrectly infer the existence of a lung cancer hazard. Alternatively, if employment in the Cold Draw Department, for example, increased the risk of heart disease, then the proportion of lung cancer deaths would be diminished in the Cold Draw Department, and in comparison, the risk of lung cancer would appear to be elevated in the Melting Department.

The statistical measures produced by the computations are the Odds Ratios of exposure (in selected Departments or jobs) among men with disease. Odds Ratios were computed from stratified 2xK Table analyses (exact analyses of odds ratios and confidence limits based on the hypergeometric statistical distribution) and by Conditional Logistic Regression⁽²⁾.

Relative Risk is the risk of disease in a certain time interval among exposed individuals relative to the risk among the unexposed. For a rare disease, such as lung cancer, Relative Risk may often be approximated by the Odds Ratios with little error. It is estimated that, even though lung cancer deaths occurred in the present study from 1976-1988, using the Odds Ratios to approximate the Relative Risk will introduce errors of less than 10%, and so in this report, Relative Risk is equated with the Odds Ratios.

RESULTS

I. The Study Population

A description of the study population is given in Table 3. Ms Hannah provided the names of 406 deceased employees. Death certificates were located for 383 men. For an additional 10 men who had died outside of Ontario, information about the cause of death was obtained from physicians' certificates to the Insurance carrier. This left 13 men whose causes of death were undetermined, and these men were excluded from the study. Of the 393 with known cause of death, portions of the work history were missing for 25. These men were excluded from the analyses which utilized job data, leaving a total of 368 in the analyses according to work area.

A) Year of Death:

The distribution of year of death is given graphically in Figure 1. Most of the men in the study died in the last 10 years, but there was a scattering of deaths back to 1961. Neither Ms. Hannah nor the employees of the Pension Department knew why the records of these earlier deaths remained in the Pension Department files when others had been removed to the Archives. It is presumed that there was no selective culling of either lung cancer victims or men with Melting Department employment, and the men who died before 1977 have thus been retained in the study population.

Table 4 gives the distribution of Year of Death by Cause (Lung Cancer vs other causes) and Table 5 gives the distribution of Year of Death by Department of Employment (Ever Melting Department versus Never Melting Department worker). Although statistical tests for differences between the columns in Tables 4 and 5 indicate no differences over all in the distributions, it must be noted that, while 34% of the men had

ever worked in the Melting Department, only 3 of the 24 men who died before 1977 had been Melting Department employees. This is a statistically unusual pattern for which there is no apparent explanation.

B) Age at Death:

Figure 2 gives the distribution of ages at death for the study subjects. Table 6 gives the distribution of ages at death by cause, and Table 7 gives the distribution of ages at death by Department. Men who had worked in the Melting Department were, on average, about 3 years younger at death than the other men.

C) Birthplace:

Cancer risk varies between countries, and it is known that immigrants to Ontario have cancer risks that are intermediate between those of their birth countries and those of Ontario born men⁽³⁾. Birthplace was abstracted from the death certificate or employment record in order to adjust for Departmental differences in ethnic makeup. Men were placed in 1 of 3 categories: 1) born in Ontario, or lung cancer risk in birthplace differs from Ontario risk by less than 10%; 2) lung cancer risk in birthplace less than 90% of Ontario risk; 3) lung cancer risk in birthplace more than 110% of Ontario risk.

Table 8 gives the distribution of birthplace by Department of Employment and Cause of Death. There were no large differences in birthplace between those men who had worked in the Melting Department and those who hadn't. Also, there was little difference in the crude lung cancer risk according to birthplace.

D) Smoking Habits:

Cigarette smoking is the leading cause of lung cancer in the Ontario population. Since the focus of this study is an assessment of the risk of lung cancer in the Melting Department, it is important to be able to determine whether any differences in lung cancer risk between Departments are due simply to differences in the smoking patterns of the workers in the various work areas. Information about the smoking habits of the workers was sought by Ms Hannah in the files of the Medical Department and from informants who knew the workers.

Information about 236 men, recorded during routine visits to the Medical Department, was found in the medical files. The information abstracted from the files included whether or not the worker reported smoking cigarettes, pipe, or cigars and the number of cigarettes smoked per day. For an additional 39 men (6 lung cancer victims and 33 controls), information about smoking was obtained from informants during June and July, 1989. In all, information was available for 275(70%) of the study population of 393 men. Sixty seven(24%) of the 275 men were non-smokers and 208(76%) were cigarette smokers.

The accuracy of the information recorded in the Medical files is uncertain, but it is likely to be unbiased in the sense that the information obtained from Melting Department workers is unlikely to be different in quality from that obtained from other employees, and, since the data was obtained, on average, many years before the time of death it is likely to be similar in quality for those who eventually died from lung cancer or from other causes. The average interval between the date the smoking information was recorded in the medical record and the time of death was 15 years for the lung cancer victims and 17 years for the men dying from other causes.

Table 9 shows the effect of cigarette smoking on lung cancer risk among Atlas employees. Men who indicated that they

were current or former cigarette smokers were classified as Smokers; non-smokers as well as pipe and cigar smokers were classified as Non-smokers. Since the relationship between cigarette smoking and lung cancer is well known from other studies, the data in this Table provide some evidence that the smoking data were qualitatively correct. Three (4%) of 67 non cigarette smokers died from lung cancer, compared to 26 (12.5%) of 208 cigarette smokers. The age-adjusted risk of lung cancer among cigarette smokers was 2.8 times that of non-smokers. The lower portion of the Table shows that there was a "dose-response" relationship between the number of cigarettes smoked and lung cancer risk.

There was no association between cigar and pipe smoking and the risk of lung cancer.

II. Results of Mortality Comparisons With the Ontario Average

This section presents the results of the comparison of the mortality pattern of the Atlas workers with the Ontario average. The numbers presented in the Tables were derived as follows. Using Table 10A as an example, we see that there were 393 deaths for analysis (All Causes, Line 1). For men of the same ages in Ontario, 27% of deaths were due to malignant disease. Multiplying $393 \times 27\%$ gives 105.7 for the "EXPECTED" number of deaths from malignancies among the Atlas workers. The ratio Observed/Expected, otherwise known as the Proportional Mortality Ratio, is thus 1.13. In other words, the proportion of deaths from Malignant Disease was 13% larger among the Atlas workers than the Ontario average. The P-value is a statistic which indicates that the probability of observing a discrepancy at least this large as the result of a statistical fluke is 0.05 (ie., 5% or 1 chance in 20). It must be borne in mind that in this Table, and the ones to follow, many comparisons will be made between the Atlas experience and the Ontario average. If many comparisons are made, it will not be unusual to see the occasional discrepancy which has a probability of occurrence of one chance in 20 or less, and is thus nominally "statistically significant" at the 5% level.

Table 10A gives the Proportional Mortality Ratios, for the entire study population. Half of the workers died from circulatory diseases, which was the same proportion as the Ontario average. Thirty percent of the deaths were from cancer, slightly higher than the Ontario average of 27%. There were 120 deaths from cancer, whereas the Ontario average is 106 for men of the same ages. The increase was attributable to deaths from respiratory cancers (43 deaths, 38 expected), cancers of the blood and lymphatic system (17 deaths, 9 expected), and prostate cancer (13 observed, 9 expected). The increased rate of death from prostate cancer was not "statistically significant".

The next 2 Tables, present an examination of the mortality data in 2 age ranges; Table 10B shows the mortality pattern among men aged less than 65, the "normal" retirement age, and Table 10C shows the pattern among men aged 65 years or more. The findings in the 2 age groups are in basic agreement, with the exception of deaths from cancers of the gastrointestinal system. There was increased mortality in the younger men, but a deficit of deaths from these causes among the older men. This discrepancy between the 2 age groups, and the increase in rates in several different anatomic locations, suggests chance fluctuation as the factor behind the apparent increase in the younger age group.

The increased mortality from haematologic malignancies is seen in both age groups, with deaths from multiple myeloma and lymphomas being primarily responsible.

III) Lung Cancer Mortality by Department

The focus of this study is an investigation of the risk of lung cancer in the Melting Department. For the remaining analyses in this report, the 25 men with incomplete work histories were excluded because the extent of their employment in the Melting Department could not be reliably determined. The pages of work history available for them indicated that 5 of these men had at some time worked in the Melting Department. Two had been Furnace operators (deaths from diabetes and cirrhosis), 1 had been a locomotive engineer (death from pneumonia), 1 had worked as a stocker (death from trauma), and 1 as a scraploader (death from heart attack). Among the 25 men excluded, there was 1 death from lung cancer. The first 10 years of the work record were missing for this man, and the only job mentioned on the subsequent page was "Bar Inspector".

Table 11 gives the Proportional Mortality Ratios for Lung Cancer by Department of employment, with a minimum of 2 years employment in any Department as the criterion for inclusion.

The 2 year limit was selected arbitrarily with the rationale that some minimum exposure would be required before a risk would become apparent. On examining this Table recall that all work histories were truncated on a date 5 years before the workers' deaths and note that these Departmental analyses are not mutually exclusive, so that if a man spent more than 2 years in each of several Departments, he would appear in the analysis for each one. Recall also that there was only 1 lung cancer death among the 25 men excluded from the Departmental analyses, so some of the PMRs for lung cancer would be slightly lower if these men could have been assigned to appropriate Departments.

Lung cancer mortality was elevated in several Departments and diminished in others; the only statistically significant difference from the Ontario average was the increased proportion in the Cold Draw Department. In the Melting Department, 9 deaths were observed, while 5.67 would have been expected.

Motivated by the lung cancer cluster in the Pit area at Slater Steels, Table 12 focusses on the Pouring Pit area of the Melting Department at Atlas. The 2-year minimum employment restriction was eliminated for this analysis. Among 264 men who had never worked in the Melting Department, 9.1% of deaths (which is the Ontario average) were due to lung cancer; among 74 men who had ever worked in the Melting Department, but never in the Pit area, 9.5% of deaths (which is again the Ontario average for men of these ages) were due to lung cancer; among the 30 men who had ever had a job (Pitman, Ladleman, Steel Pourer) in the Pit area, 27% of deaths were due to lung cancer, a rate 2.71 times the Ontario average. The excess lung cancer mortality among the Pit workers is statistically significant ($P = 0.01$; 1-tailed test) in comparison with the Ontario average, and the difference is of borderline significance ($P = 0.061$) when the comparison is between the 30 Pouring Pit workers and the 338 other Atlas workers. The lower

portion of Table 12 shows the internal comparison assuming that the 25 men with incomplete work histories had never been Pitworkers.

Table 13 gives the overall mortality pattern for men who had ever been pouring pit workers, and there is no major anomaly apart from the lung cancer excess.

IV) Internal Comparisons of Lung Cancer Mortality

In this section of the report, the risk of lung cancer in various Atlas work areas will be examined, using the Atlas workers themselves as the comparison population. Three men whose death certificates mentioned lung cancer, but whose deaths were coded to other causes (2 heart attacks and 1 pneumonia) will be included among the lung cancer cases. None of these men had ever been a Pitworker.

These analyses will examine how lung cancer risk varies by work area, length and time of exposure, age, year of death, and birthplace. Table 11 showed lung cancer mortality by Department, but individual workers were permitted to appear in more than 1 category. The following analyses will attempt to examine Departmental risk, taking into account the fact that some men will have worked in more than 1 Department. Once again, the major focus will be the Pouring Pit area of the Melting Department.

A) Lung Cancer Risk Among Pouring Pit Workers

For this analysis, men who had ever worked as Pitmen, Ladlemen, or Steel Pourers earlier than 5 years before their deaths are classified as Pitworkers. The total number of years employed as a Pitworker, up to 5 years before death, was computed for each man, and all the workers were assigned to one of three exposure categories. Category 1 includes 329 men who had never been Pitworkers; Category 2 includes 11 men who had

been Pitworkers for less than 2 years; and, Category 3 includes 19 men who had been Pitworkers for 2 years or more.

1) Effect of Age on Risk

Table 14 shows lung cancer risk among Pitworkers in 5 age groups. There were no lung cancer deaths among the 3 Pitworkers who were younger than 55 or older than 84 at death. Table 19A shows that adjusting for age has essentially no effect on the risk estimates and that there were no statistically significant differences among the age strata.

2) Effect of Year of Death

Table 15 shows lung cancer risk among Pitworkers in 3 calendar periods. Among the men in the study, there was only one death of a Pitworker before 1977. Table 19A shows that adjusting for calendar period has essentially no effect on the risk estimates and that there were no statistically significant differences among the time strata. In the detailed analyses of dose-response, there will be no adjustment for year of death.

3) Effect of Birthplace

Table 16 shows that adjusting for birthplace has essentially no effect on the risk estimates and that there were no statistically significant differences among the birthplace strata. In the detailed analyses of dose-response, there will be no adjustment for birthplace.

4) Effect of Cigarette Smoking

Information about cigarette smoking habits was not available for all the men. Table 17 gives the distribution of information about smoking by work area and diagnosis. Data was

lacking for 23% of Pitworkers and 23% of men in other work areas. The percentage of non smokers was smaller among Pitworkers than among men in other work areas.

Table 18 gives the lung cancer risk among Pitworkers according to smoking habit, and Table 19B gives the risk estimates adjusted for age and smoking. The data is presented in 2 ways in this Table; firstly, removing men with missing information from the analysis, and secondly, including men with missing information as a third smoking stratum in the analysis. It should be noted that the study group is so small that removing the 23% of the population with missing information has a substantial effect on the size of the risk estimates for the 2 Pitworker exposure groups. More importantly, it will be noted that adjusting for age and smoking has only a minimal effect on the size of the Relative Risk and that the increased risk among Pitworkers with more than 2 years of employment persists after adjustment for smoking.

5) Adjusted Lung Cancer Risk and "Dose-Response" for Pitworkers

The data in Tables 19A and 19B shows that there is a highly significant trend in lung cancer risk with increasing work time in the Pit area. The increased risk among men with less than 2 years exposure is not statistically significant (but, with only 11 individuals in this category, the statistical power to observe a significant result is less than 20%). Among men with more than 2 years of work in the Pit area, the 4-fold increase in risk is statistically significant. Because there are only 19 individuals in this category, the 95% confidence intervals are very broad.

B) Lung Cancer Risk Among Pit Workers Accounting For Other Jobs

As indicated in Table 11, the PMRs for lung cancer were

elevated in some Departments and decreased in others. The increased risk in certain Departments such as Cold Draw and Conditioning might reflect: 1) occupational exposures in these Departments; 2) that some Pitworkers also worked in these Departments; 3) a statistical fluke. In order to investigate lung cancer risk in a number of Departments simultaneously, a Conditional Logistic Regression Analysis was performed, with stratification on the 5 age groups defined previously. The results are presented in Table 20.

Entering PITWORKER into the model by itself produces results similar to the stratified age-adjusted analysis presented in Table 19. Of the other Departmental exposures, only 2 years or more in the Cold Draw Department was significantly associated with an increased lung cancer risk. However, when, in Model 5, account is taken of employment both as a Pitworker and in the Cold Draw Department, then the risk attributable to Cold Draw employment is no longer statistically significant.

One may thus conclude that there is no statistical evidence of increased risk in areas other than the Pouring Pit area of the Melting Department. Random statistical fluctuations appear to increase risk in some Departments, while at the same time, lung cancer risk appears to be diminished in others.

C) Time Interval Between Exposure and Death

There is generally a substantial time interval between exposure to a cancer-causing agent and development of the disease. This fact has important implications for current workers, since risks being observed now might reflect exposure conditions of many years ago, conditions which might no longer exist. This section of the report presents an analysis which attempts to determine when the exposures most associated with death from lung cancer took place.

Table 21 divides the years before death into 5-year "Time Windows" and indicates, for each "Window", the numbers of men who had been employed as Pitworkers, the numbers who eventually died from lung cancer, and the risk of death from lung cancer among men who had been Pitworkers in that "Time Window" compared to men who had not been Pitworkers at that time. Note that these "Windows" are not mutually exclusive; a man who worked for 7 years as a Pitworker will thus appear in at least 2 "Windows" (depending upon whether his service was continuous or broken). Note also that a man will be counted as a Pitworker even if his exposure in any "Window" was only 1 day and that men are placed in the "NOT PITWORKER" category even if a particular "Time Window" occurs before they began work at Atlas.

The numbers of men employed as Pitworkers ranged from a minimum of 4, at 5 to 9 years before death, to a maximum of 15, at 20 to 24 years before death. Approximately 11% of NEVER PIT workers died from lung cancer, while among the Pitworkers the percentage ranged from 20 to 33% in the various time windows. The numbers of subjects are small, and the only risk that is statistically significant is the Relative Risk of 4.1 among men who were employed as Pitworkers 20 to 24 years before their deaths.

D) Latency

Recall that in the preceding analysis the time windows were not mutually exclusive, and men were counted as Pitworkers in any time interval without regard to the number of days employed in the job. Table 22 gives the lengths of time in each time window for the 8 lung cancer victims.

The following analysis, using Conditional Logistic Regression, analyzes lung cancer risk taking account of the 5 age strata introduced in Table 14, and uses as a measure of

exposure the number of years employed as a Pitworker in each time window. The data were analyzed for overlapping 5-year time windows, 5-9 years before death, 6-10 years, 7-11 years, and so on. Figure 3 displays the results of the analysis. The vertical axis gives a measure of how well exposures in any time window predicted who would develop lung cancer. Values greater than 3.85 on the vertical axis are "statistically significant", and the larger the value on the vertical axis, the stronger the association between years of exposure in that time window and the risk of lung cancer. The upper curve gives the result when only employment as a "PITMAN" was counted as exposure, and the lower curve gives the result when employment as "PITMAN", "LADLEMAN", or "STEEL POURER" was counted as exposure. The results indicate that the best explanation of risk is given by exposures incurred between about 18 and 29 years before death.

E) Dose-Response

This section presents the results of a quantitative investigation of the relationship between length of employment as a Pitworker, taken as a surrogate measure of "dose", and the risk of lung cancer. Motivated by the preceding analysis, the number of YEARS EMPLOYED AS A PITWORKER was calculated for each man for each of the 3 time windows 5 to 19, 19 to 29, and 29 or more years before death.

Table 23 gives the results of the analysis for the 18 to 29 year time window. The first part of the Table shows the lung cancer risk for men in each of 3 dose groups, compared to men who were not Pitworkers. The risk increases steadily with increasing length of exposure in this 11 year interval, reaching a Relative Risk of about 6 for men with an average length of exposure of 9.1 years. The number of individuals in each category is so small, however, that for none of the groups is the increased risk statistically significant. The increasing Trend is, however, significant: $P = 0.03$.

To overcome the problems with grouped data, Conditional Logistic Regression analysis was used to investigate the dose-response relationship, using the actual "Years of Exposure as a Pitworker" as the measure of dose for each individual. Two models were fitted to the data, a standard logistic model, which assumes an exponential relationship between years of exposure and the risk of lung cancer, and a second model, which permits a power-function relationship between exposure and risk.

In this second model:

$$\text{Log (Relative Risk)} = A \times \text{Log}(\text{Years As Pitworker} + 1)$$

$$\Rightarrow \text{Relative Risk} = (\text{Years as Pitworker} + 1)^A.$$

(One is added on to the years worked so as to give a Relative Risk of 1 for no exposure.)

The value for "A" was estimated from the data to be 0.77, with a Standard Error of 0.33. The exponent for the power function relationship is thus 0.77, but the confidence limits include the value of 1.0, a linear relationship between the Years of Employment as a Pitworker and the Risk of Lung Cancer. Figure 4 shows the results. The grouped data points are the age-adjusted Relative Risks from Table 23, and the curve is the regression fit to the ungrouped data. The statistically significant dose-response relationship is clearly evident in the Figure. Adjustment for smoking had only a minor effect upon the slope.

When the 2 other time windows were examined, there was no significant association between years of exposure in the intervals 5 to 19 years, and 29 years or more, with the risk of lung cancer.

F) Calendar Time When Exposures Occurred

It is of considerable interest to know when the exposures in the 18 to 29 year exposure window occurred. Table 24 shows the dates during which the 8 men who died from lung cancer were

assigned to jobs in the Pit area. Examination of this Table shows that, for these men, exposures in the 18 to 29 year time window occurred during the years 1949 to 1962.

V. Environmental Measurements in the Melting Department

The Health and Safety Support Services Branch of the Ministry of Labour carried out air sampling in the Melting Department in January, 1989 and the results were presented to the Joint Health and Safety Committee on May 24, 1989. The air sampling was done to quantify worker exposures to total dust, metals, silica, carbon monoxide, carbon dioxide, sulphur dioxide, oxides of nitrogen, and benzene solubles. Three men whose job was Steel Pourer were included among the 41 men sampled with personal pumps. Their exposures were similar to the average in the rest of the Melt Shop. Further data is now available, and a summary is presented in an accompanying document from the Health and Safety Support Services Branch.

VI. Other Causes of Death

Tables 10A-C showed the mortality pattern for the Atlas workforce as a whole, and compared it with the "average" pattern in Ontario. The only organ systems which stood out as having unusual patterns were the gallbladder and the blood and lymphatic systems. Is there an occupational association, or are these random statistical fluctuations?

Table 25 shows the lengths of times that men dying of these diseases spent in the various Departments at Atlas (2 year minimum for inclusion). The number of deaths is small and it is difficult to draw any conclusions. Two of three men who died from gallbladder cancer had worked for more than 2 years in the Forge Department, but one of them had entered the

Department only 10 years before his death. Three of the men who died from multiple myeloma had worked in the finishing Department; one had been a saw operator, a second had been a labourer and cropper, and the third had been a cropper and core cutter. An occupational connection with cancer of the bone marrow seems unlikely. It is concluded that the increased mortality from gallbladder cancer and cancers of the blood and lymphatic systems most likely represent the play of chance.

VII. Mortality Patterns by Department

Tables 26 to 40 show the mortality pattern for a variety of causes of death in the various Departments at Atlas. It is tempting to look over these Tables to look for clusters of disease in particular locations. It must be remembered, however, that among the several hundred PMRs that one might examine, a number would be expected to be "statistically significant" solely due to statistical flukes. No striking anomalies are identified.

DISCUSSION

An investigation at Slater Steels in Hamilton found a cluster of lung cancer deaths among employees of the Melting Department. Extensive environmental sampling was performed at the plant by the Ministry of Labour, but no definitive conclusions could be drawn about a cause for the increased risk of lung cancer. At the conclusion of the Slater investigation, 2 explanations for the lung cancer cluster in the Melt Shop were plausible. Firstly, the cluster may have been a statistical fluke, unrelated to occupational exposures. Alternatively, occupational factors may have played a role. As is usually the case with epidemiologic investigations, it was not possible to decide between these alternatives on the basis of the initial study, and it was decided to seek additional information by performing a similar investigation in another plant. The focus of the present report has been an investigation of lung cancer risk among Melting Department employees of Atlas Specialty Steels in Welland.

The results of the two studies, taken together, indicate a strong relationship between occupational exposures associated with the pouring of steel into metal ingot molds in the Pit areas of the Melt Shops, and the risk of lung cancer. Cigarette smoking is known to be the major cause of lung cancer in Ontario, and ideally one would like to compare men of similar smoking habits when looking for occupational risk factors for lung cancer. Information about the smoking habits of the study subjects was not available at Slater Steels, but information was obtained for 70% of the study population at Atlas Specialty Steels. Analysis indicated that the increased lung cancer risk in the Pit area could not be explained solely by differences in cigarette smoking habit.

The process of pouring steel into casting cases was eliminated at Slater in 1968 in favour of continuous casting, but it is still carried on at Atlas. A statistical analysis of

the association of the times between employment in the Pit area and death from lung cancer suggests that the relevant exposures took place at Atlas during the 1950s and early 1960s. This finding might have 2 important interpretations, apart from statistical chance. Firstly, it might mean that certain materials or processes were in use between 1950 and 1962 that are associated with the subsequent development of lung cancer. Secondly, this result might reflect the operation of biological processes, for on the one hand, it may be that it takes at least 15 years or more for hazardous exposures to result in death from lung cancer, and, on the other hand, tissues damaged by toxic agents many years before might be repaired or eliminated, so that if a cancer has not appeared by 30 or so years after exposure, there might be a very small chance of its ever appearing.

Because of the time lag, determination of what agent or agents might have been responsible for the lung cancer risk in the Pouring Pit areas requires an investigation into historical practices at Atlas and Slater because of changes in the materials used in the pouring areas. These inquiries are in progress and are important because the toxic agents, or similar ones, might still be used in other work places or might be re-introduced into industrial use without adequate safeguards.

There are no environmental measurements from the earlier era. Current air sampling for a wide variety of toxic agents in the Melting Department at Atlas finds concentrations of hazardous materials to be within their suggested limits. It was found that, for those chemical substances measured, there were essentially no differences in the exposures of men working in the Pit area and in other workplaces in the Melting Department. Although it is possible that unmeasured hazardous agents might be present, this finding would suggest that current pouring pit workers are not at higher risk than their fellow workers.

Environmental assessment is thus unable to find evidence

that current conditions in the Pit area place workers at increased risk of lung cancer, but it is reasonable to presume that surviving men who worked in the Pit area before the mid-1960s remain at increased risk of lung cancer. The best measure to decrease their risk would be to advise any cigarette smokers among them to quit smoking. It is known that cigarette smoking increases the risk of lung cancer caused by a variety of occupational carcinogens, including asbestos and radon. It is also believed that smoking cessation leads to a lessening of risk. It is thus strongly recommended that all men who worked in the Pouring area be encouraged to quit smoking.

ACKNOWLEDGEMENTS

The author thanks Lee Hannah, Co-ordinator of Occupational Health at Atlas Specialty Steels, for her enthusiastic assistance with this investigation. Mrs. Beauparlant and her colleagues in the Pension Department provided copies of the work histories, and Mr Smalyga, Superintendent of Steelmaking, provided valuable information about the Melting Department.

Monique Boulard and Nancy Wilk, hygienists in the Health and Safety Support Services Branch of the Ministry of Labour, co-ordinated the hazard evaluation and the air sampling program at the plant.

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DISTRIBUTION OF YEAR OF DEATH FOR ATLAS STUDY SUBJECTS

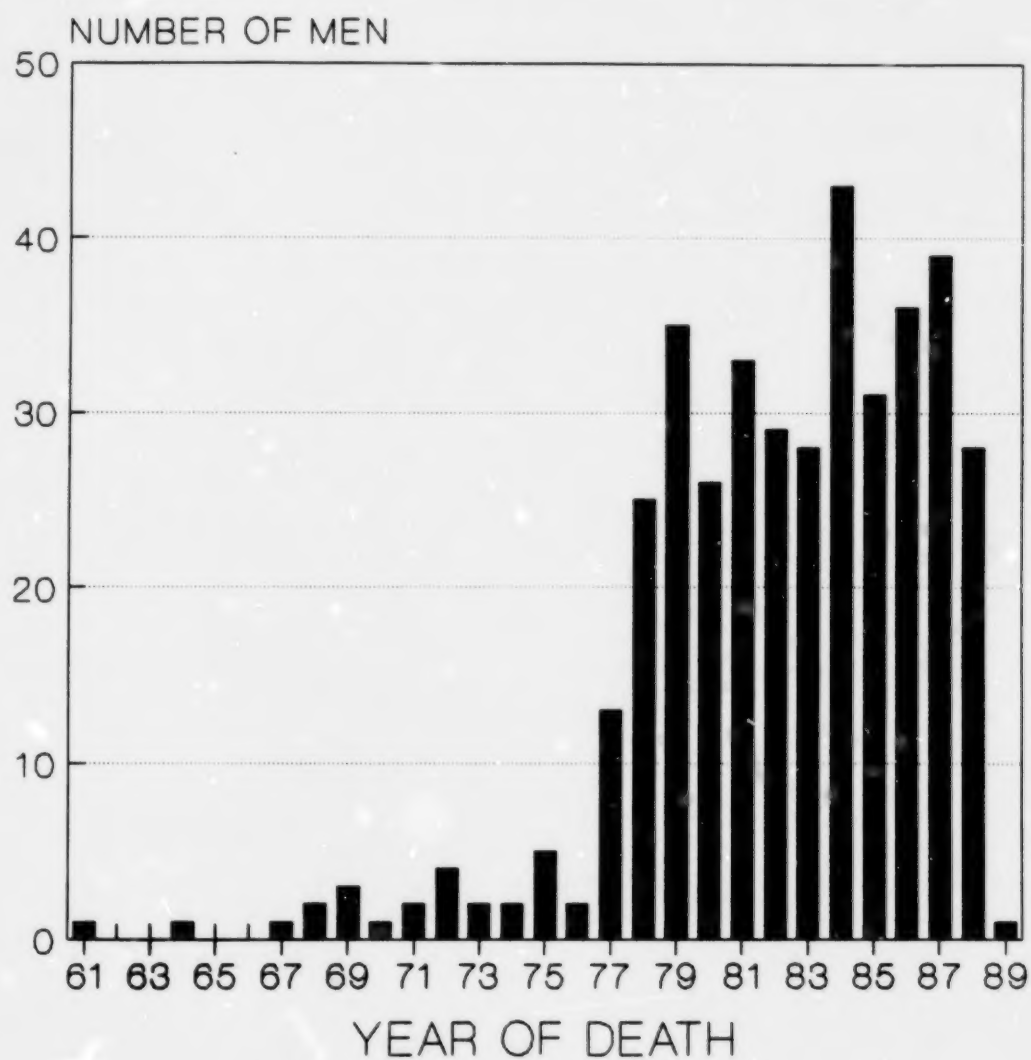


FIGURE 1

DISTRIBUTION OF AGES AT DEATH FOR ATLAS STUDY SUBJECTS

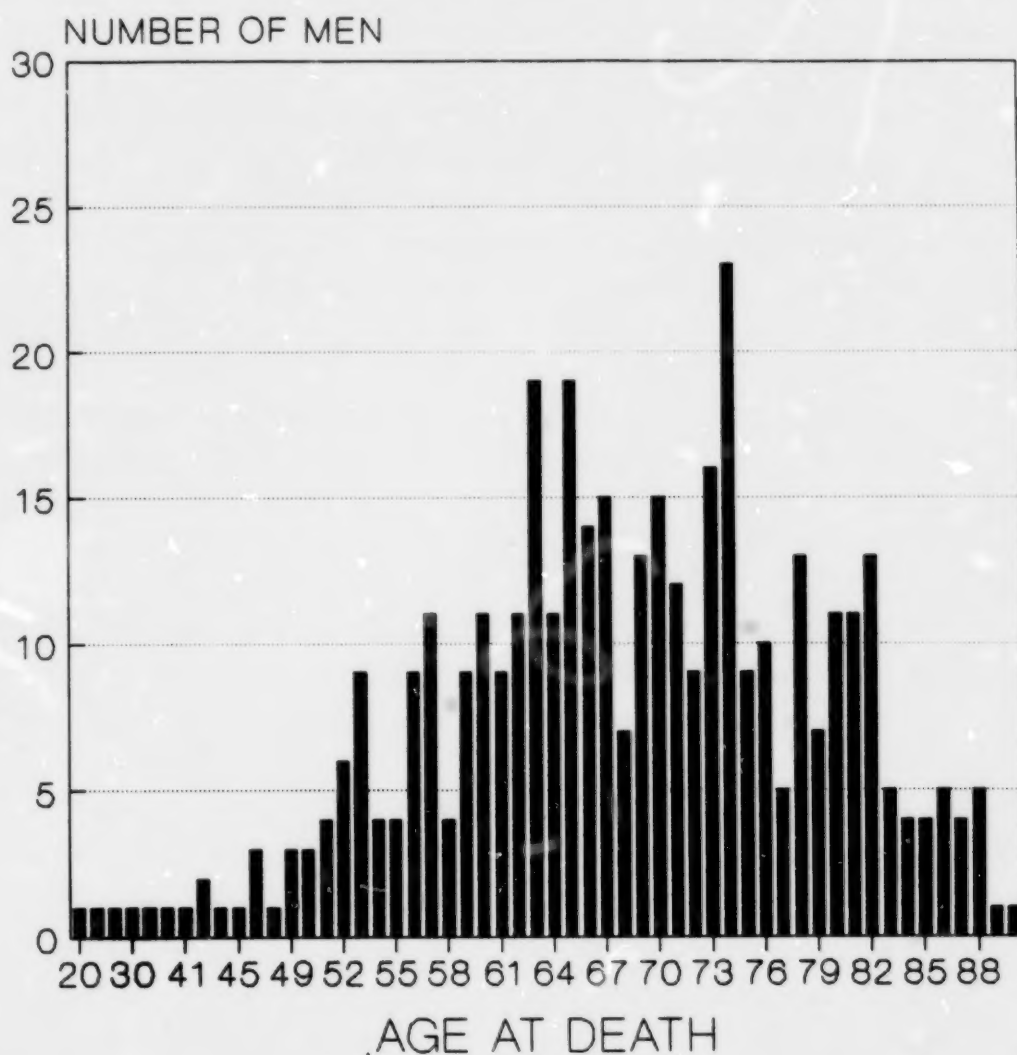


FIGURE 2

FIGURE 3

THIS FIGURE SHOWS THE RESULTS FROM USING A MATHEMATICAL MODEL TO RELATE EXPOSURES DURING 5-YEAR "TIME WINDOWS" TO THE RISK OF LUNG CANCER. BASICALLY, THE QUESTION ASKED IS: IS THERE AN ASSOCIATION BETWEEN EXPOSURE AS A PITWORKER IN ANY OF THESE TIME INTERVALS AND THE RISK OF DEATH FROM LUNG CANCER? THE STRONGER THE ASSOCIATION BETWEEN EXPOSURE AND LUNG CANCER, THEN THE HIGHER THE VALUE ON THE VERTICAL AXIS. VALUES LESS THAN 4 ON THE VERTICAL AXIS INDICATE SIMPLY RANDOM ASSOCIATIONS. VALUES GREATER THAN 4 SHOW ASSOCIATIONS BETWEEN EXPOSURE AND THE RISK OF LUNG CANCER WHICH ARE STATISTICALLY SIGNIFICANT.

THE POINTS ALONG THE HORIZONTAL AXIS GIVE THE STARTING POINT OF THE 5-YEAR TIME WINDOW. FOR EXAMPLE, "5" CORRESPONDS TO THE 5-9 YEAR TIME WINDOW, AND "20" TO THE 20-24 YEAR TIME WINDOW.

THE VALUES ON THE VERTICAL AXIS GIVE A MEASURE OF ASSOCIATION. TECHNICALLY, THE VALUES ARE MINUS TWICE THE CHANGE IN LOG LIKELIHOOD (OR DEVIANCE) OF THE FITTED MODELS.

ASSOCIATION BETWEEN LUNG CANCER RISK AND TIME OF EXPOSURE

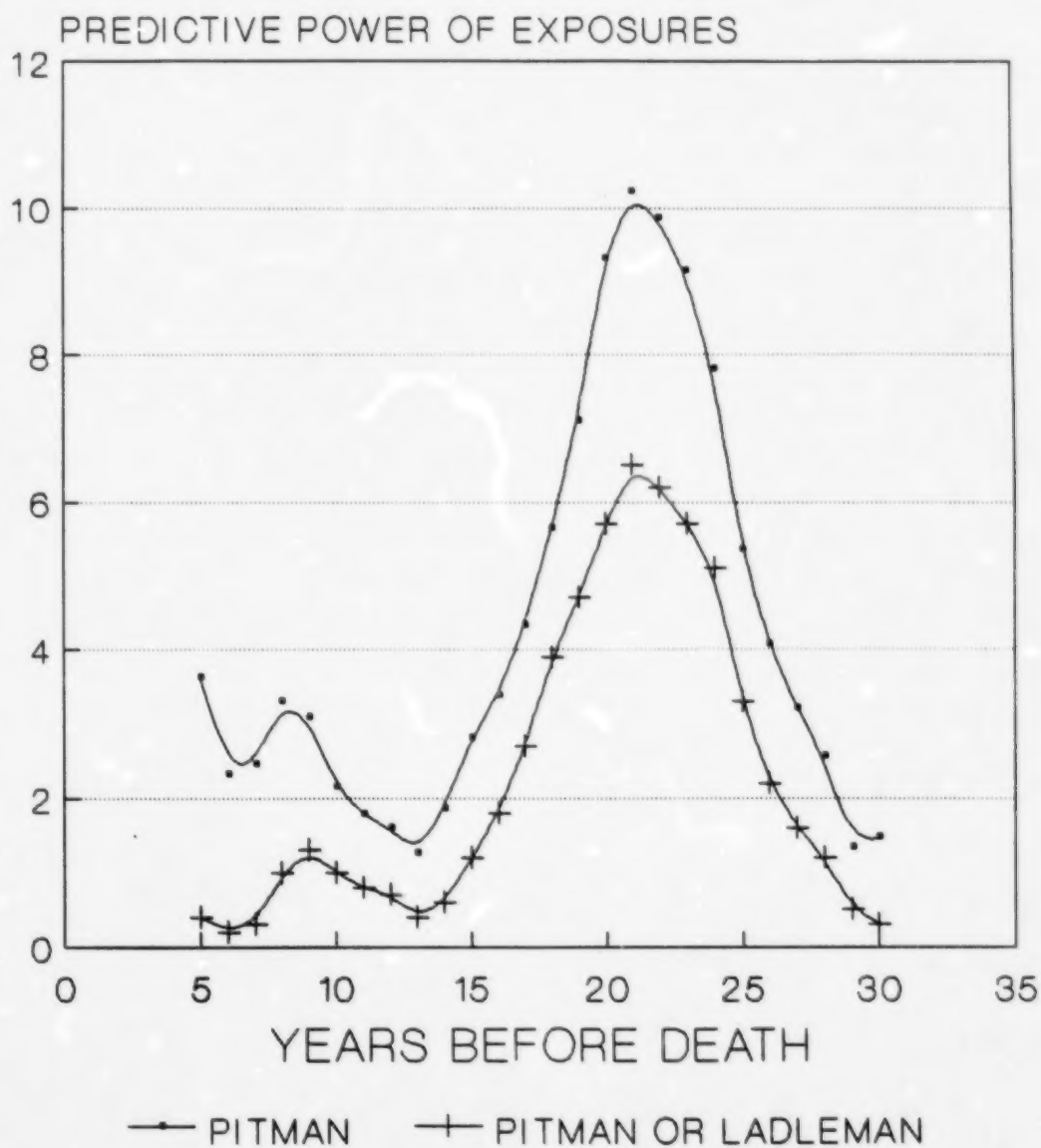


FIGURE 3

FIGURE 4
DOSE-RESPONSE RELATIONSHIP FOR
RISK OF LUNG CANCER VERSUS YEARS AS A PITWORKER

THE HORIZONTAL AXIS GIVES THE NUMBER OF YEARS EMPLOYED AS A PITWORKER IN THE 11-YEAR INTERVAL 18-29 YEARS BEFORE DEATH. THE VERTICAL AXIS GIVES THE RISK OF LUNG CANCER RELATIVE TO MEN WHO HAD NEVER BEEN EMPLOYED AS PITWORKERS.

THE 4 SQUARE DATA POINTS GIVE THE RESULTS FOR 4 EXPOSURE GROUPINGS:

- 1) NEVER A PITWORKER
- 2) PITWORKER LESS THAN 2 YEARS
- 3) PITWORKER FOR 2 - 5 YEARS
- 4) PITWORKER FOR MORE THAN 5 YEARS

THE CURVE GIVES THE DOSE-RESPONSE CURVE WHEN THE CALCULATION USES THE ACTUAL NUMBER OF YEARS OF EXPOSURE FOR EACH WORKER, RATHER THAN COMBINING INDIVIDUALS IN THE 4 GROUPS ABOVE. THE EQUATION FOR THIS CURVE IS:

$$\text{RELATIVE RISK} = (\text{YEARS OF EMPLOYMENT AS PITWORKER} + 1)^{0.77} .$$

RELATIVE RISK OF LUNG CANCER VERSUS YEARS AS PITWORKER

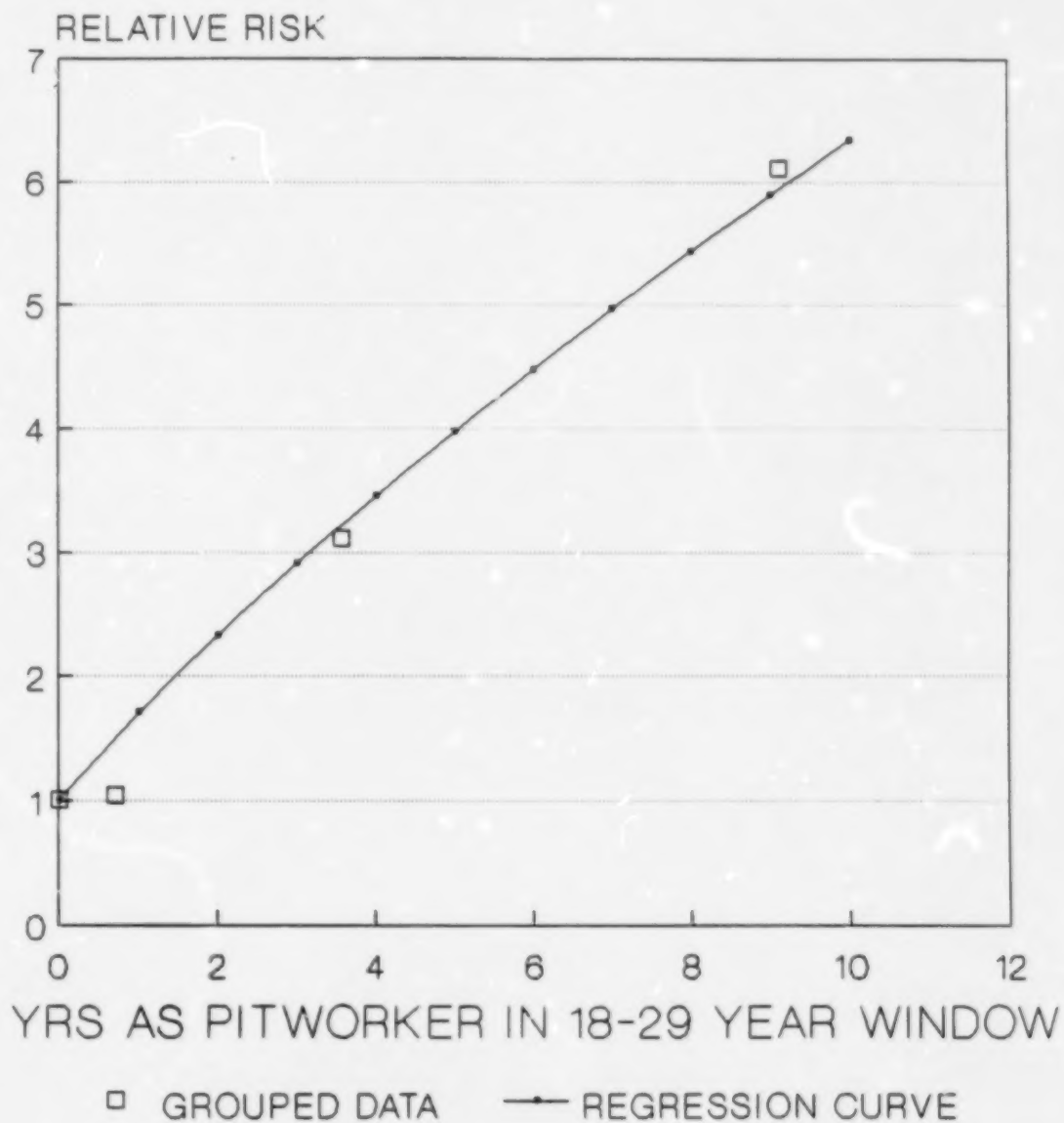


FIGURE 4

TABLE 1: DEPARTMENTS CODED FROM ATLAS WORK HISTORIES

Bar Mill
Blooming Mill
Brick
Cold Draw
Chipping and Grinding
Clerical and Security
Conditioning
Cutting and Welding
Finishing
Forge
Fuel
Heat Treatment and Annealing
Industrial Engineering
Inspection
Laboratories: Chemical and Metallurgical
Labour Pool
Maintenance
 Electrical
 Machine Shop
 Millwright
 Pipefitter
 Rigger
 Welding

Melting
Plate Mill
Production Planning
Rolling mill
Sheet Mill
Shipping
Stores
Strip and Tube Mill
Transportation
Utilities
Warehouse

Table 2: MELTING DEPARTMENT JOBS CODED FOR ANALYSIS.
JOB TITLES GIVEN THE SAME CODE ARE ON THE SAME LINE

Alloy Stocker, Warehouseman
Burner, Torch Cutter
Billet Handler
Casting Machine Operator, Burning Machine
Charging Machine Operator, Furnace Loader, Charger and Shaw
Crane
Crane Operators
 #10 and #11, Stripper Crane
 Alloy Storage
 Furnace Crane
 Ladle Crane Operator
 Mobile Crane, Mobile Crane Fireman, Steam Crane
 Mold Crane
 Supply Crane

Crusher Operator
Electric Arc Furnace Operator and Helper: Helpers 1, 2, 3
Hot Top Liner
Labourer, Roustabout, Utilityman
Ladleman, 1st Steel Pourer; Ladle Preparer, 2nd Steel Pourer
Locomotive Engineer - Fireless
Locomotive Engineer - Pit
Mold and Hot Top Preparer, Moldman
Pipe Eliminator Maker
Pitman, Pouring Pit Labourer, 3rd Steel Pourer
Scrap Loader, Scrap Press Operator, Scrap Shearman
Spark Tester
Stopper Maker
Stripper Operator
Head Stocker, Weighmaster; Stocker's Helper, Weighmaster's
Helper
Supplyman
Tungsten Recovery Operator

Table 3: DESCRIPTION OF THE STUDY GROUP

I.	Number of names received from Company	406
II.	Death Certificates Located	383
III.	Insurance Data About Cause of Death	10
	9 Circulatory System causes	
	1 Traumatic cause	
IV.	Number with known cause of death	<u>393</u>
V.	Number with unknown cause of death	13 EXCLUDED
VI.	Number of men eligible for study	393
VII.	Number With Incomplete Work History Cards	25
VIII.	Number in Departmental Analyses	368

**TABLE 4: DISTRIBUTION OF YEAR OF DEATH FOR LUNG CANCER
 VICTIMS AND OTHER STUDY SUBJECTS**

YEAR OF DEATH	NUMBER OF DEATHS FROM		TOTAL
	LUNG CANCER	OTHER CAUSES	
1961	0	1	1
1964	0	1	1
1967	0	1	1
1968	0	2	2
1969	0	3	3
1970	0	1	1
1971	0	2	2
1972	0	4	4
1973	0	2	2
1974	0	1	1
1975	0	4	4
1976	1	1	2
1977	2	9	11
1978	3	20	23
1979	2	32	34
1980	5	20	25
1981	3	28	31
1982	1	27	28
1983	2	23	25
1984	9	33	42
1985	6	22	28
1986	2	30	32
1987	5	31	36
1988	1	27	28
1989	0	1	1
TOTAL	42	326	368

Statistical Test for Difference Between Lung Cancer and Other Causes: Not Significant P = 0.821

**TABLE 5: DISTRIBUTION OF YEAR OF DEATH FOR MELTING
DEPARTMENT AND OTHER EMPLOYEES**

YEAR OF DEATH	EVER MELT SHOP WORKER	NEVER MELT SHOP WORKER	TOTAL
1961	0	1	1
1964	0	1	1
1967	0	1	1
1968	0	2	2
1969	0	3	3
1970	0	1	1
1971	0	2	2
1972	2	2	4
1973	0	2	2
1974	0	1	1
1975	0	4	4
1976	1	1	2
1977	3	8	11
1978	6	17	23
1979	11	23	34
1980	8	17	25
1981	6	25	31
1982	5	23	28
1983	5	20	25
1984	15	27	42
1985	10	18	28
1986	10	22	32
1987	14	22	36
1988	9	19	28
1989	0	1	1
TOTAL	105	263	368

Statistical Test for Difference Between Departments:
No% Significant P = 0.949

**TABLE 6: DISTRIBUTION OF AGES AT DEATH FOR LUNG CANCER
 VICTIMS AND OTHER STUDY SUBJECTS**

AGE AT DEATH	NUMBER OF DEATHS FROM		TOTAL
	LUNG CANCER	OTHER CAUSES	
LESS THAN 45	0	9	9
45 TO 54	3	28	31
55 TO 64	14	80	94
65 TO 74	15	116	131
75 TO 84	9	75	84
85 OR MORE	1	18	19
TOTAL	42	326	368

**TABLE 7: DISTRIBUTION OF AGE AT DEATH FOR MELTING
 DEPARTMENT AND OTHER EMPLOYEES**

AGE AT DEATH	EVER MELT SHOP WORKER	NEVER MELT SHOP WORKER	TOTAL
LESS THAN 45	4	5	9
45 TO 54	10	21	31
55 TO 64	35	59	94
65 TO 74	30	101	131
75 TO 84	24	60	84
85 OR MORE	2	17	19
TOTAL	105	263	368

**TABLE 8: DISTRIBUTION OF BIRTHPLACE BY DEPARTMENT
 and CAUSE OF DEATH**

I.

Department	Lung Cancer Rate in Birthplace Compared to Ontario		
	Equal	Lower	Higher
Ever Melting Department	50 (48%)	15 (14%)	40 (38%)
Never Melting Department	144 (55%)	25 (10%)	94 (36%)

II.

Diagnosis	Lung Cancer Rate in Birthplace Compared to Ontario		
	Equal	Lower	Higher
Men With Lung Cancer	20 (10.3%)	6 (15%)	16 (11.9%)
Men Without Lung Cancer	174 (89.7%)	34 (85%)	118 (88.1%)

TABLE 9: CIGARETTE SMOKING AND THE RISK OF LUNG CANCER

1) Workers Classified as Smokers or Non-Smokers (275 men)

	LUNG CANCER		RELATIVE RISK and 95% CONFIDENCE INTERVAL
	NO	YES	
NON SMOKERS	64	3	1.0
SMOKERS	182	26	2.79 [0.81 - 14.9]

Age-adjusted risk of lung cancer among
smokers compared to non-smokers = 2.79 P = 0.06

2) Workers Classified by Cigarettes Per Day (257 men)*

	LUNG CANCER		RELATIVE RISK and 95% CONFIDENCE INTERVAL .
	NO	YES	
NON SMOKERS	62	3	1.0
< 20 CIGS/DAY	49	5	2.43 [0.43 - 16.9]
20+ CIGS/DAY	118	21	3.30 [0.93 - 17.9]

Test for Trend: P = 0.02

*The numbers of men are smaller than in Section 1 because the number of cigarettes per day was unrecorded for some smokers and because men less than 45 years of age are excluded from the analysis in this section.

**TABLE 10A: MORTALITY PATTERN AMONG ATLAS EMPLOYEES
COMPARED TO PATTERN AMONG ONTARIO MALES**

CAUSE OF DEATH	OBSERVED	EXPECTED	OBS/EXP	P
All Causes	393			
All Malignancies	120	105.7	1.13	0.05*
Respiratory	43	38.3	1.12	0.24*
Lung	40	36.4	1.10	0.30*
Larynx	3	1.5	2.02	
Digestive	31	31.9	0.97	
Esophagus	2	2.9	0.69	
Stomach	8	5.8	1.37	
Intestines/Rectum	13	13.2	0.99	
Liver	0	1.2	0	
Pancreas	4	5.6	0.71	
Gallbladder	3	0.83	3.61	0.05*
Blood and Lymphatics	17	8.6	1.98	<0.02
Leukemia	4	3.57	1.12	
Multiple Myeloma	5	1.64	3.04	0.03*
Lymphoma	8	3.37	2.37	0.04
Kidney	2	2.37	0.84	
Bladder	3	3.43	0.88	
Prostate	13	8.74	1.49	0.21
Skin	2	1.41	1.42	
Brain	1	2.73	0.37	
All Others	8	8.02	1.00	
Circulatory Disease	191	190.9	1.00	
Heart Attack	147	136.7	1.08	0.27
Stroke	21	25.5	0.82	
Others	23	28.7	0.80	
Respiratory Disease	24	28.6	0.84	0.36
Glandular and Metabolic	6	7.6	0.79	
Digestive Diseases	17	16.5	1.03	
Cirrhosis	11	7.8	1.41	0.33
Urinary System	3	4.0	0.75	
Accidents, Suicide	21	21.1	1.00	

* These P-values are from 1-tailed statistical tests

TABLE 10B: MORTALITY PATTERN AMONG ATLAS EMPLOYEES LESS THAN 65 YEARS OF AGE COMPARED TO PATTERN AMONG ONTARIO MALES

CAUSE OF DEATH	OBSERVED	EXPECTED	OBS/EXP	P
All Causes	142			
All Malignancies	50	41.9	1.19	0.12*
Respiratory	18	16.6	1.08	
Lung	16	15.7	1.02	
Larynx	2	0.7	2.81	
Digestive	18	12.3	1.47	0.15
Esophagus	2	1.3	----	
Stomach	3	2.3	----	
Intestines/Rectum	6	4.8	1.25	
Liver	0	0.6	0	
Pancreas	4	2.3	1.77	
Gallbladder	2	0.31	6.52	0.04*
Blood and Lymphatics	6	3.4	1.76	0.26
Leukemia	2	1.32	----	
Multiple Myeloma	1	0.61	----	
Lymphoma	3	1.49	2.01	
Kidney	2	1.14	----	
Bladder	1	0.87	----	
Prostate	2	1.35	----	
Skin	0	0.77	----	
Brain	1	1.66	----	
All Others	2	3.70	0.54	
Circulatory Disease	57	62.0	0.92	0.58
Heart Attack	47	48.6	0.97	
Stroke	2	5.4	0.37	0.19
Others	8	7.9	----	
Respiratory Disease	1	5.6	0.18	0.04
Glandular and Metabolic	1	2.5	0.40	
Digestive Diseases	12	8.0	1.50	0.22
Cirrhosis	8	5.0	1.59	
Urinary System	1	0.9	----	
Accidents, Suicide	16	14.4	1.11	

* These P-values are from 1-tailed statistical tests

TABLE 10C: MORTALITY PATTERN AMONG ATLAS EMPLOYEES AGED 65 YEARS OR MORE, COMPARED TO PATTERN AMONG ONTARIO MALES

CAUSE OF DEATH	OBSERVED	EXPECTED	OBS/EXP	P
All Causes	251			
All Malignancies	70	63.8	1.10	0.47*
Respiratory	25	21.7	1.15	0.27*
Lung	24	20.7	1.16	0.26*
Larynx	1	0.8	-----	
Digestive	13	19.6	0.66	0.16
Esophagus	0	1.6	-----	
Stomach	5	3.6	1.40	
Intestines/Rectum	7	8.3	0.84	
Liver	0	0.7	0	
Pancreas	0	3.4	0	0.06
Gallbladder	1	0.52	-----	
Blood and Lymphatics	11	5.2	2.13	0.04
Leukemia	3	2.26	-----	
Multiple Myeloma	4	1.04	3.86	0.02*
Lymphoma	5	1.89	2.65	0.04*
Kidney	0	1.23	-----	
Bladder	2	2.56	-----	
Prostate	11	7.38	1.49	0.26
Skin	2	0.63	3.15	
Brain	0	1.08	-----	
All Others	6	4.32	1.39	
Circulatory Disease	134	128.9	1.04	0.52
Heart Attack	100	88.1	1.14	0.12
Stroke	19	20.0	0.95	
Others	15	20.8	0.72	
Respiratory Disease	23	23.0	-----	
Glandular and Metabolic	5	5.1	-----	
Digestive Diseases	5	8.5	0.59	
Cirrhosis	3	2.7	-----	
Urinary System	2	3.1	0.64	
Accidents, Suicide	5	6.7	0.75	

* These P-values are from 1-tailed statistical tests

**TABLE 11: LUNG CANCER MORTALITY AMONG ATLAS EMPLOYEES
BY DEPARTMENT (MINIMUM 2 YEARS EMPLOYMENT IN DEPARTMENT)**

DEPARTMENT	# OF MEN	OBSERVED	EXPECTED	OBS/EXP	P
MELTING	55	9	5.67	1.59	0.12
ANNEALING	23	3	2.17	----	
BAR MILL	15	0	1.38	0	
BLOOMING MILL	40	6	3.67	1.63	0.17
BRICK	9	1	0.79	----	
CHIPPING	8	0	0.58	----	
COLD DRAW	39	9	3.78	2.38	0.02
CONDITIONING	51	7	5.09	1.37	0.25
FINISHING	32	3	2.93	----	
FORGE	27	3	2.80	----	
INSPECTION	36	2	3.67	0.55	
LABS	20	1	1.98	----	
MAINTENANCE	61	7	5.90	1.19	
PIPEFITTING	5	1	0.51	----	
ROLLING MILL	31	3	2.99	----	
SHEET MILL	34	1	3.36	0.30	
STRIP MILL	26	3	2.64	----	
TRANSPORTATION	9	0	0.87	----	
WELDING	13	2	1.37	----	

NOTES: Departmental assignments are not mutually exclusive.
Individuals will contribute to each Department in
which they were employed for 2 years or more.

All P - Values are 1-sided.

When observed and expected differ by less than 1,
then no ratio is given

**TABLE 12: LUNG CANCER MORTALITY ACCORDING TO EMPLOYMENT
IN THE MELTING DEPARTMENT POURING AREA:
JOB TITLES INCLUDE PITMAN, LADLEMAN, AND STEEL POURER**

WORK AREA	# OF MEN	OBSERVED	EXPECTED	OBS/EXP	P
Ever worked in Pouring Pit	30	8	2.95	2.71	0.01
Ever worked in Melting Dept, but never in Pit	74	7	7.24	0.97	
Never worked in Melting Dept	264	24	23.84	1.01	

**II. Assume 25 Men Excluded for Incomplete Histories were
Never Pit Workers**

WORK AREA	# OF MEN	OBSERVED	EXPECTED	OBS/EXP	P
Ever worked in Pouring Pit	30	8	2.95	2.71	0.01
Never worked in Pouring Pit	363	32	33.42	0.96	

**TABLE 13: MORTALITY PATTERN AMONG MEN WHO HAD EVER BEEN POURING
PIT WORKERS, COMPARED TO PATTERN AMONG ONTARIO MALES**

CAUSE OF DEATH	OBSERVED	EXPECTED	PMR	P
All Causes	30			
All Malignancies	16	8.42	1.90	0.01
Respiratory	8	3.10	2.58	
Lung	8	2.95	2.71	0.01
Larynx	0	0.12	----	
Digestive	4	2.52	1.58	0.50
Esophagus	0	0.24	----	
Stomach	1	0.45	----	
Intestines/Rectum	3	1.04	2.89	0.09
Pancreas	0	0.44		
Gallbladder	0	0.06		
Blood and Lymphatics	1	0.65	----	
Leukemia	1	0.36	----	
Multiple Myeloma	0	0.13	----	
Lymphoma	0	0.17	----	
Bladder	0	0.28	----	
Prostate	1	0.72	----	
Skin	0	0.11	----	
Brain	0	0.20	----	
Circulatory Disease	10	14.63	0.68	0.28
Heart Attack	10	10.41	----	
Stroke	0	1.97	0	
Respiratory Disease	2	2.27	----	
Cirrhosis	1	0.53	----	
Accidents, Suicide	1	1.13	----	

TABLE 14: LUNG CANCER RISK OF PIT WORKERS IN 5 AGE GROUPS

EXPOSURE CATEGORY*	LUNG CANCER		Risk Relative to NEVER PIT (95% Confidence Interval)
	NO	YES	

Ages: 45 to 54

1	27	3	1.00
2	1	0	0
3	0	0	Undefined

Ages: 55 to 64

1	75	10	1.00
2	2	1	3.67 (0.06 to 76.6)
3	3	3	7.23 (0.85 to 61.8)

Ages: 65 to 74

1	109	12	1.00
2	4	1	2.25 (0.04 to 25.4)
3	3	2	5.91 (0.45 to 57.2)

Ages: 75 to 84

1	68	8	1.00
2	2	0	0
3	5	1	1.69 (0.03 to 18.2)

Ages: 85 or More

1	16	1	1.00
2	0	0	Undefined
3	2	0	0

* Exposure Group 1: Never a Pouring Pit Worker
 Exposure Group 2: Pitman or Ladleman for Less than 2 Years
 Exposure Group 3: Pitman or Ladleman for 2 Years or More

TABLE 15: LUNG CANCER RISK OF PIT WORKERS IN 3 TIME INTERVALS

EXPOSURE CATEGORY*	LUNG CANCER		Risk Relative to NEVER PIT (95% Confidence Interval)
	NO	YES	
<u>Year of Death: Before 1977</u>			
1	21	1	1.00
2	1	0	0
3	0	0	Undefined
<u>Year of Death: 1977 to 1982</u>			
1	125	13	1.00
2	3	0	0
3	4	3	7.03 (0.93 to 46.8)
<u>Year of Death: 1983 to 1989</u>			
1	149	20	1.00
2	5	2	2.95 (0.26 to 19.6)
3	9	3	2.47 (0.40 to 11.0)
<u>Average Over All Years Combined</u>			
1	295	34	1.00
2	9	2	1.87 (0.2 to 9.7) ^e
3	13	6	3.75 (1.10 to 11.5) ^e

* Exposure Group 1: Never a Pouring Pit Worker
 Exposure Group 2: Pitman or Ladleman for Less than 2 Years
 Exposure Group 3: Pitman or Ladleman for 2 Years or More

^e Test for Common Risk Over Year of Death Groupings ==> No Significant Difference

TABLE 16: LUNG CANCER RISK OF PIT WORKERS BY BIRTHPLACE

EXPOSURE CATEGORY*	LUNG CANCER		Risk Relative to NEVER PIT (95% Confidence Interval)
	NO	YES	

Born in Ontario:

1	156	17	1.00
2	6	0	0
3	3	3	8.96 (1.11 to 72.3)

Rate in Birthplace Less Than Ontario:

1	31	3	1.00
2	2	1	4.80 (0.07 to 122)
3	1	2	17.46 (0.73 to 1256)

Rate in Birthplace More Than Ontario:

1	108	14	1.00
2	1	1	7.49 (0.09 to 611)
3	9	1	0.86 (0.02 to 7.08)

Average Over All Birthplaces Combined

1	295	34	1.00
2	9	2	1.99 (0.2 to 10.3) ^e
3	13	6	3.94 (1.15 to 12.1) ^e

* Exposure Group 1: Never a Pouring Pit Worker
 Exposure Group 2: Pitman or Ladleman for Less than 2 Years
 Exposure Group 3: Pitman or Ladleman for 2 Years or More

^e Test for Common Risk Over Birthplace Groupings ==> No Significant Difference

TABLE 17: AVAILABILITY OF INFORMATION ABOUT SMOKING HABIT

1) All Workers Over 45 Years of Age in Work Area Analysis:

CIGARETTE SMOKING HABIT				
	NONSMOKER	SMOKER	UNKNOWN	TOTAL
	-----	-----	-----	-----
NEVER PITWORKER	65 (20%)	187 (57%)	77 (23%)	329
PITWORKER	2 (7%)	21 (70%)	7 (23%)	30

2) Availability by Diagnosis:

CIGARETTE SMOKING HABIT				
	NONSMOKER	SMOKER	UNKNOWN	TOTAL
	-----	-----	-----	-----
LUNG CANCER	3 (7%)	26 (62%)	13 (31%)	42
OTHER CAUSES	64 (20%)	182 (57%)	71 (22%)	317

3) Pitworkers According to Lung Cancer Status:

CIGARETTE SMOKING HABIT				
	NONSMOKER	SMOKER	UNKNOWN	TOTAL
	-----	-----	-----	-----
LUNG CANCER	0	6	2	8
OTHER CAUSES	2	15	5	22

TABLE 18: LUNG CANCER RISK AMONG PIT WORKERS BY SMOKING HABIT

EXPOSURE CATEGORY*	LUNG CANCER		Risk Relative to NEVER PIT (95% Confidence Interval)
	NO	YES	

Non Smokers:

1	62	3	1.00
2	0	0	Undefined
3	2	0	0

Smokers:

1	167	20	1.00
2	9	1	0.93 (0.02 to 7.3)
3	6	5	6.84 (1.51 to 29.8)

Smoking Habit Unknown:

1	66	11	1.00
2	0	1	Undefined
3	5	1	1.20 (0.02 to 12.3)

- * Exposure Group 1: Never a Pouring Pit Worker
 Exposure Group 2: Pitman or Ladleman for Less than 2 Years
 Exposure Group 3: Pitman or Ladleman for 2 Years or More

TABLE 19A: ADJUSTED LUNG CANCER RISK AMONG PIT WORKERS

EXPOSURE CATEGORY*	LUNG CANCER		Risk Relative to NEVER PIT (95% Confidence Interval)
	NO	YES	

No adjustment for Age or Year of Death:

1	295	34	1.00
2	9	2	1.92 (0.19 to 9.9)
3	13	6	3.98 (1.16 to 12.2)

Test for Trend: P = 0.008

Adjusted for Age:

1	295	34	1.00
2	9	2	1.86 (0.19 to 9.4) ^e
3	13	6	4.06 (1.17 to 12.6) ^e

Adjusted for Year of Death:

1	295	34	1.00
2	9	2	1.87 (0.19 to 9.6) ^e
3	13	6	3.75 (1.10 to 11.5) ^e

Adjusted for Age and Year of Death Together:

1	295	34	1.00
2	9	2	1.76 (0.18 to 8.9) ^e
3	13	6	3.74 (1.09 to 11.5) ^e

- * Exposure Group 1: Never a Pouring Pit Worker
 Exposure Group 2: Pitman or Ladleman for Less than 2 Years
 Exposure Group 3: Pitman or Ladleman for 2 Years or More

^e Test for Common Risk Over Age and Year of Death Groupings ==>
 No Significant Differences

TABLE 19B: LUNG CANCER RISK AMONG PIT WORKERS ADJUSTED FOR SMOKING

EXPOSURE CATEGORY*	LUNG CANCER		Risk Relative to NEVER PIT (95% Confidence Interval)
	NO	YES	
<u>No adjustment for Age or Smoking(275 Men With Smoking Histories):</u>			
1	229	23	1.00
2	9	1	1.11 (0.02 to 8.6)
3	8	5	6.15 (1.46 to 23.5)
Test for Trend: P = 0.006			

Adjusted for Age and 2 Categories of Smoking⁺(275 Men):

1	229	23	1.00
2	9	1	0.97 (0.02 to 7.6)
3	8	5	7.05 (1.48 to 33.7)

No adjustment for Age or Smoking(359 Men):

1	295	34	1.00
2	9	2	1.92 (0.19 to 9.9)
3	13	6	3.98 (1.16 to 12.2)

Adjusted for Age and 3 Categories of Smoking⁺⁺(359 Men):

1	295	34	1.00
2	9	2	1.90 (0.19 to 9.9)
3	13	6	4.15 (1.13 to 14.1)

- * Exposure Group 1: Never a Pouring Pit Worker
 Exposure Group 2: Pitman or Ladleman for Less than 2 Years
 Exposure Group 3: Pitman or Ladleman for 2 Years or More

⁺Two smoking categories are: 1) Non smokers; 2) Smokers

⁺⁺3 smoking categories are: 1) Non smokers; 2) Smokers; 3) Unknown

**TABLE 20: ANALYSIS OF LUNG CANCER RISK IN THE PIT AREA
ACCOUNTING FOR EMPLOYMENT IN OTHER DEPARTMENTS**

**LOGISTIC REGRESSION
MODEL**

MODEL 1: PITWORKER*		Likelihood Ratio = 6.288	P = 0.043
PIT < 2 yrs	RR = 1.83 (0.38 to 8.75)		
PIT > 2 yrs	RR = 4.06 (1.44 to 11.47)		
MODEL 2: BLOOMING MILL		Likelihood Ratio = 0.310	P = 0.568
BLOOM > 2 yrs	RR = 1.31 (0.52 to 3.33)		
MODEL 3: COLD DRAW		Likelihood Ratio = 4.277	P = 0.039
COLD > 2 yrs	RR = 2.25 (1.08 to 4.69)		
MODEL 4: CONDITIONING		Likelihood Ratio = 2.725	P = 0.099
COND > 2 yrs	RR = 1.83 (0.91 to 3.69)		
MODEL 5: PITWORKER + COLD DRAW		Likelihood Ratio = 6.288 + 2.977	P = 0.043 + 0.084
PIT < 2	RR = 1.81 (0.37 to 8.75)		
PIT > 2	RR = 3.49 (1.21 to 10.10)		
COLD > 2	RR = 2.00 (0.94 to 4.26)		
MODEL 6: PITWORKER + CONDITIONING		Likelihood Ratio = 6.288 + 2.545	P = 0.043 + 0.111
PIT < 2	RR = 1.61 (0.33 to 7.80)		
PIT > 2	RR = 4.07 (1.43 to 11.56)		
COND > 2	RR = 1.81 (0.88 to 3.70)		
MODEL 7: PITWORKER + COLD DRAW + CONDITIONING		Likelihood Ratio = 6.3 + 2.9 + 2.5	P = 0.043 + 0.09 + 0.11
PIT < 2	RR = 1.59 (0.32 to 7.83)		
PIT > 2	RR = 3.54 (1.22 to 10.26)		
COLD > 2	RR = 1.97 (0.92 to 4.21)		
COND > 2	RR = 1.79 (0.87 to 3.67)		

NOTES: * PITWORKER is a Factored Variable with 2 levels.
PIT < 2 (Less than 2 Years as Pitworker) and
PIT > 2 (2 Years or More as Pitworker)

TABLE 21: LUNG CANCER RISK ACCORDING TO TIME OF EMPLOYMENT AS PITWORKER FOR MEN AGED 45 YEARS OR MORE AT DEATH

1) 5 to 9 years Before Death

	PITWORKER	NOT PITWORKER	
Cases	1 (25%)	41 (11%)	N Exposed = 4
Controls	3	314	

Relative Risk = 2.553; 90% Confidence limits: 0.40 to 22.3

2) 10 to 14 Years Before Death

	PITWORKER	NOT PITWORKER	
Cases	2 (29%)	40 (11%)	N Exposed = 7
Controls	5	312	

Relative Risk = 3.120; 90% Confidence limits: 0.82 to 15.4

3) 15 to 19 Years Before Death

	PITWORKER	NOT PITWORKER	
Cases	3 (27%)	39 (11%)	N Exposed = 11
Controls	8	309	

Relative Risk = 2.971; 90% Confidence limits: 0.72 to 10.8

4) 20 to 24 Years Before Death

	PITWORKER	NOT PITWORKER	
Cases	5 (33%)	37 (11%)	N Exposed = 15
Controls	10	307	

Relative Risk = 4.149; 90% Confidence limits: 1.37 to 12.1

5) 25 to 29 Years Before Death

	PITWORKER	NOT PITWORKER	
Cases	4 (29%)	38 (11%)	N Exposed = 14
Controls	10	307	

Relative Risk = 3.232; 90% Confidence limits: 0.96 to 10.1

6) 30 or More Years Before Death

	PITWORKER	NOT PITWORKER	
Cases	2 (20%)	40 (11%)	N Exposed = 10
Controls	8	309	

**TABLE 22: THE NUMBER OF YEARS OF EMPLOYMENT AS A PITWORKER
IN EACH OF 6 TIME WINDOWS
FOR 8 MEN WHO DIED FROM LUNG CANCER**

Number of Years of Employment as Pitworker

ID	W5_9	W10_14	W15_19	W20_24	W25_29	W30PLUS	AGE DEATH
1	0.00	0.00	0.99	3.07	1.50	0.00	72
2	0.00	2.26	0.00	0.00	0.00	0.00	71
3	0.00	0.00	0.00	2.79	0.43	0.00	56
4	0.00	0.00	2.39	5.00	4.58	0.00	78
5	2.41	4.76	0.00	0.00	0.00	0.00	58
6	0.00	0.00	3.78	5.00	5.00	10.30	64
7	0.00	0.00	0.00	0.00	0.00	0.02	68
8	0.00	0.00	0.00	0.35	0.00	0.00	55

Definitions: W5_9 is the Time Window 5 to 9 Years Before Death
W10_14 is the Time Window 10 to 14 Years Before Death
W15_19 is the Time Window 15 to 19 Years Before Death
W20_24 is the Time Window 20 to 24 Years Before Death
W25_29 is the Time Window 25 to 29 Years Before Death
W30PLUS is the Time Window 30 or More Years Before Death

TABLE 23: RISK OF LUNG CANCER BY YEARS OF EMPLOYMENT AS A PITWORKER IN THE 11 YEAR INTERVAL, 18 TO 29 YEARS BEFORE DEATH

I) TABULAR ANALYSIS

YEARS AS PITWORKER	LUNG CANCER		AGE-ADJUSTED RELATIVE RISK (90% CONFIDENCE INTERVAL)
	NO	YES	
NONE	301	37	1.0
LESS THAN 2 (Mean: 0.70)	8	1	1.04 (0.05 - 6.37)
2 to 5 (Mean: 3.56)	5	2	3.10 (0.44 - 16.2)
MORE THAN 5 (Mean: 9.11)	3	2	6.11 (0.65 - 35.6)

TEST FOR TREND: $P = 0.029$

II) REGRESSION ANALYSIS (Adjusted for Age in 5 Strata)

Model I: $\text{Log (RR)} = A \times \text{YEARS} \implies \text{RR} = \exp(A \times \text{YEARS})$

Best Fit: $A = 0.23$ $P = 0.014$

Increase in Relative Risk for Each Years Additional Exposure
 $\text{RR} = 1.263$ 90% C. I. (1.08 to 1.48)

MODEL II: $\text{Log RR} = A \times \log(\text{YEARS} + 1) \implies \text{RR} = (\text{YEARS} + 1)^A$

Best Fit: $A = 0.77$ Standard Error of $A = 0.33$
 $P = 0.020$

TABLE 24, PAGE 1: DATES AND LATENCIES OF JOBS HELD BY
POURING PIT WORKERS DYING FROM LUNG CANCER

ID: 11 DATE of DEATH: 03/14/84 AGE AT DEATH: 72

JOB TITLE: PITMAN YEARS in JOB: 1.02
 STOP DATE: 04/23/56 YEARS FROM STOP TO DEATH: 27.89
 START DATE: 04/18/55 YEARS FROM START TO DEATH: 28.91

JOB TITLE: PITMAN YEARS in JOB: 3.55
 STOP DATE: 04/15/62 YEARS FROM STOP TO DEATH: 21.91
 START DATE: 09/28/58 YEARS FROM START TO DEATH: 25.46

JOB TITLE: PITMAN YEARS in JOB: 0.99
 STOP DATE: 09/15/68 YEARS FROM STOP TO DEATH: 15.49
 START DATE: 09/18/67 YEARS FROM START TO DEATH: 16.49

ID: 101 DATE of DEATH: 01/21/80 AGE AT DEATH: 71

JOB TITLE: PITMAN YEARS in JOB: 2.26
 STOP DATE: 08/05/68 YEARS FROM STOP TO DEATH: 11.46
 START DATE: 05/01/66 YEARS FROM START TO DEATH: 13.72

ID: 126 DATE of DEATH: 01/07/81 AGE AT DEATH: 56

JOB TITLE: LADLE OP YEARS in JOB: 0.57
 STOP DATE: 03/05/56 YEARS FROM STOP TO DEATH: 24.84
 START DATE: 08/09/55 YEARS FROM START TO DEATH: 25.42

JOB TITLE: PITMAN YEARS in JOB: 1.48
 STOP DATE: 08/26/57 YEARS FROM STOP TO DEATH: 23.37
 START DATE: 03/05/56 YEARS FROM START TO DEATH: 24.84

JOB TITLE: PITMAN YEARS in JOB: 1.17
 STOP DATE: 03/28/60 YEARS FROM STOP TO DEATH: 20.78
 START DATE: 01/26/59 YEARS FROM START TO DEATH: 21.95

TABLE 24, PAGE 2: DATES AND LATENCIES OF JOBS HELD BY
POURING PIT WORKERS DYING FROM LUNG CANCER

ID: 238 DATE of DEATH: 07/07/79 AGE AT DEATH: 78

JOB TITLE: PITMAN YEARS in JOB: 11.97
 STOP DATE: 12/01/61 YEARS FROM STOP TO DEATH: 17.60
 START DATE: 12/13/49 YEARS FROM START TO DEATH: 29.56

ID: 245 DATE of DEATH: 02/14/87 AGE AT DEATH: 58

JOB TITLE: PITMAN YEARS in JOB: 5.33
 STOP DATE: 09/12/77 YEARS FROM STOP TO DEATH: 9.42
 START DATE: 05/14/72 YEARS FROM START TO DEATH: 14.75

JOB TITLE: LADLE PREP YEARS in JOB: 0.34
 STOP DATE: 06/08/78 YEARS FROM STOP TO DEATH: 8.69
 START DATE: 02/05/78 YEARS FROM START TO DEATH: 9.02

JOB TITLE: PITMAN YEARS in JOB: 1.54
 STOP DATE: 03/01/82 YEARS FROM STOP TO DEATH: 4.96
 START DATE: 08/17/80 YEARS FROM START TO DEATH: 6.49

ID: 266 DATE of DEATH: 03/28/85 AGE AT DEATH: 64

JOB TITLE: PITMAN YEARS in JOB: 2.66
 STOP DATE: 02/10/44 YEARS FROM STOP TO DEATH: 41.13
 START DATE: 06/14/41 YEARS FROM START TO DEATH: 43.79

JOB TITLE: PITMAN YEARS in JOB: 0.54
 STOP DATE: 10/01/46 YEARS FROM STOP TO DEATH: 38.49
 START DATE: 03/19/46 YEARS FROM START TO DEATH: 39.03

JOB TITLE: PITMAN YEARS in JOB: 20.87
 STOP DATE: 01/12/69 YEARS FROM STOP TO DEATH: 16.21
 START DATE: 02/29/48 YEARS FROM START TO DEATH: 37.08

TABLE 24, PAGE 3: DATES AND LATENCIES OF JOBS HELD BY
POURING PIT WORKERS DYING FROM LUNG CANCER

ID: 280 DATE of DEATH: 02/28/85 AGE AT DEATH: 68

JOB TITLE: PITMAN YEARS in JOB: 0.02
STOP DATE: 09/12/50 YEARS FROM STOP TO DEATH: 34.46
START DATE: 09/04/50 YEARS FROM START TO DEATH: 34.49

ID: 326 DATE of DEATH: 04/28/84 AGE AT DEATH: 55

JOB TITLE: PITMAN YEARS in JOB: 0.35
STOP DATE: 03/15/60 YEARS FROM STOP TO DEATH: 24.12
START DATE: 11/09/59 YEARS FROM START TO DEATH: 24.47

TABLE 25: YEARS OF EMPLOYMENT IN VARIOUS DEPARTMENTS AMONG MEN DYING FROM GALLBLADDER CARCINOMA, LYMPHOMA, AND MULTIPLE MYELOMA

1) Gallbladder Carcinoma

AGEDEATH	BLOOMYRS	CONDYRS	FORGEYRS	ROLLYRS	SHEETYRS
65	13.30	8.15	0.00	0.00	0.00
62	0.00	0.00	4.57	2.38	20.77
56	0.34	0.00	14.78	0.00	0.00

2) Malignant Lymphoma

A) Non-Hodgkins Lymphoma

AGEDEATH	YRSMELT	YRSE_R	CONDYRS	FORGEYRS	ANNEALYRS	SHEETYRS
74	0.00	33.14	0.00	0.00	0.00	0.00
66	0.25	0.00	17.76	0.00	0.00	0.00
63	0.00	0.00	0.00	0.17	32.60	0.00
57	12.60	0.00	0.00	0.32	0.00	11.22
69	0.00	0.00	0.00	0.00	0.00	0.00
76	23.62	0.00	0.00	0.00	0.00	0.00
63	0.00	0.00	0.00	37.69	0.00	0.00
B) Hodgkins Lymphoma						
71	0.00	0.00	0.56	3.61	22.13	0.00

3) Multiple Myeloma

AGEDEATH	ROLLYRS	INSPECTYRS	FINYRS	BARYRS	BLOOMYRS	YRSE_R
64	7.01	0.00	0.00	22.05	1.92	0.00
68	0.00	19.53	16.94	0.00	0.00	0.00
86	0.00	0.00	11.56	0.00	0.00	3.11
80	0.00	0.00	13.87	0.00	10.73	0.00
77	0.00	0.00	0.00	0.00	0.00	0.00

Definitions: BLOOM = Blooming Mill; COND = Conditioning Dept
 ROLL = Rolling Mill; SHEET = Sheet Mill
 E_R = Maintenance; ANNEAL = Heat Treatment & Anneal
 INSPECT = Inspection Dept; FIN = Finishing Dept;

TABLE 26: MORTALITY PATTERN AMONG ATLAS EMPLOYEES WITH A MINIMUM OF 2 YEARS IN THE MELTING DEPARTMENT

CAUSE OF DEATH	OBSERVED	EXPECTED	OBS/EXP	P
All Causes	55			
All Malignancies	23	15.9	1.45	
Respiratory				
Lung	9	5.7	1.59	
Larynx	0	0.2	0	
Digestive	7	4.7	1.48	0.39
Esophagus	0	0.5	0	
Stomach	1	0.8	1.25	
Intestines/Rectum	6	1.9	3.13	0.01*
Pancreas	0	0.9	0	
Gallbladder	0	0.1	0	
Blood and Lymphatics	3	1.3	2.41	0.28
Leukemia	2	0.5	4.00	0.09
Multiple Myeloma	0	0.25	0	
Lymphoma	2	0.41	4.90	0.06*
Bladder	0	0.5	0	
Prostate	1	1.19	0.84	
Skin	1	0.22	4.62	
Brain	0	0.43	0	
Circulatory Disease	20	26.3	0.76	
Heart Attack	14	19.2	0.73	
Stroke	2	3.3	0.61	
Respiratory Disease	5	3.8	1.33	
Cirrhosis	4	1.2	3.38	

* These P-values are from 1-tailed statistical tests

TABLE 27: MORTALITY PATTERN AMONG ATLAS EMPLOYEES WITH AT LEAST 2 YEARS IN THE MAINTENANCE OR BRICK DEPARTMENTS

CAUSE OF DEATH	OBSERVED	EXPECTED	OBS/EXP	P
All Causes	86			
All Malignancies	21	23.9	0.88	
Respiratory	10	8.8	1.14	
Lung	10	8.3	1.20	
Larynx	0	0.34	0	
Digestive	4	7.2	0.55	
Esophagus	0	0.7	0	
Stomach	2	1.3	1.54	
Intestines/Rectum	2	3.0	0.67	
Pancreas	0	1.3	0	
Gallbladder	0	0.2	0	
Blood and Lymphatics	1	1.9	0.53	
Lymphoma	1	0.4	2.27	
Bladder	0	0.8	0	
Prostate	2	2.1	0.97	
Skin	0	0.3	0	
Brain	1	0.6	1.81	
Circulatory Disease	46	42.6	1.08	
Heart Attack	36	30.6	1.18	
Stroke	2	5.7	0.35	
Respiratory Disease	8	6.4	1.24	
Cirrhosis	2	1.56	1.28	

TABLE 28: MORTALITY PATTERN AMONG ATLAS EMPLOYEES WITH AT LEAST 2 YEARS IN THE BLOOMING MILL

CAUSE OF DEATH	OBSERVED	EXPECTED	OBS/EXP	P
All Causes	40			
All Malignancies	16	10.7	1.49	0.06
Respiratory				
Lung	6	3.67	1.63	
Larynx	0	0.14	0	
Digestive	5	3.3	1.52	
Esophagus	0	0.3	0	
Stomach	1	0.6	1.61	
Intestines/Rectum	3	1.4	2.21	
Pancreas	0	0.6	0	
Gallbladder	1	0.09	11.1	
Blood and Lymphatics	2	0.9	2.32	
Leukemia	0	.4	0	
Multiple Myeloma	1	.17	5.83	
Lymphoma	1	.32	3.12	
Bladder	0	0.4	0	
Prostate	1	0.9	1.07	
Skin	0	0.12	0	
Brain	0	0.25	0	
Circulatory Disease	18	20.1	0.89	
Heart Attack	11	14.4	0.77	
Stroke	3	2.8	1.07	
Respiratory Disease	2	3.0	0.67	
Cirrhosis	0	0.7	0	

TABLE 29: MORTALITY PATTERN AMONG ATLAS EMPLOYEES WITH AT LEAST 2 YEARS IN THE BAR MILL

CAUSE OF DEATH	OBSERVED	EXPECTED	OBS/EXP	P
All Causes	15			
All Malignancies	2	4.0	0.49	
Respiratory				
Lung	0	1.4	0	
Larynx	0	0.05	0	
Digestive	0	1.25	0	
Esophagus				
Stomach				
Intestines/Rectum				
Pancreas				
Gallbladder				
Blood and Lymphatics	2	0.33	6.13	
Leukemia	1	0.14	7.1	
Multiple Myeloma	1	0.06	16.1	
Lymphoma	0	0.12	0	
Bladder	0	0.14	0	
Prostate	0	0.35	0	
Skin	0	0.04	0	
Brain	0	0.09	0	
Circulatory Disease	9	7.5	1.20	
Heart Attack	3	5.39	0.56	
Stroke	4	1.03	3.88	
Respiratory Disease	0	1.14	0	
Cirrhosis	1	0.26	3.89	

TABLE 30: MORTALITY PATTERN AMONG ATLAS EMPLOYEES WITH AT LEAST
2 YEARS IN THE COLD DRAW DEPARTMENT

CAUSE OF DEATH	OBSERVED	EXPECTED	OBS/EXP	P
All Causes	39			
All Malignancies	17	10.9	1.56	0.03
Respiratory				
Lung	9	3.78	2.38	<0.01
Larynx	0	0.15	0	
Digestive	3	3.29	0.91	
Esophagus	0	0.31	0	
Stomach	1	0.59	1.69	
Intestines/Rectum	0	1.35	0	
Pancreas	1	0.58	1.74	
Gallbladder	0	0.08	0	
Blood and Lymphatics	1	0.87	1.15	
Leukemia	1	0.36	2.78	
Multiple Myeloma	0	0.18	0	
Lymphoma	0	0.33	0	
Bladder	2	0.36	5.60	<0.01
Prostate	0	0.93	0	
Skin	0	0.14	0	
Brain	0	0.27	0	
Circulatory Disease	14	19.1	0.73	
Heart Attack	11	13.6	0.81	
Stroke	3	2.59	1.16	
Respiratory Disease	2	2.89	0.69	
Cirrhosis	2	0.7	2.86	

TABLE 31: MORTALITY PATTERN AMONG ATLAS EMPLOYEES WITH AT LEAST 2 YEARS IN THE CHEMICAL OR METALLURGICAL LABS

CAUSE OF DEATH	OBSERVED	EXPECTED	OBS/EXP	P
All Causes	20			
All Malignancies	4	5.60	0.71	
Respiratory				
Lung	1	1.98	0.51	
Larynx	0	0.08	0	
Digestive	1	1.66	0.60	
Esophagus	0	0.16	0	
Stomach	0	0.30	0	
Intestines/Rectum	1	0.67	1.50	
Pancreas	0	0.30	0	
Gallbladder	0	0.04	0	
Blood and Lymphatics	0	0.46	0	
Leukemia				
Multiple Myeloma				
Lymphoma				
Bladder	0	0.17	0	
Prostate	2	0.37	5.34	<0.01
Skin	0	0.09	0	
Brain	0	0.18	0	
Circulatory Disease	12	9.40	1.28	
Heart Attack	10	6.93	1.44	
Stroke	2	1.11	1.79	
Respiratory Disease	1	1.26	0.79	
Cirrhosis	0	0.52	0	

TABLE 32: MORTALITY PATTERN AMONG ATLAS EMPLOYEES WITH AT LEAST 2 YEARS IN THE CHIPPING DEPARTMENT

CAUSE OF DEATH	OBSERVED	EXPECTED	OBS/EXP	P
All Causes	8			
All Malignancies	0	1.88	0	
Respiratory				
Lung				
Larynx				
Digestive				
Esophagus				
Stomach				
Intestines/Rectum				
Pancreas				
Gallbladder				
Blood and Lymphatics				
Leukemia				
Multiple Myeloma				
Lymphoma				
Bladder				
Prostate				
Skin				
Brain				
Circulatory Disease	5	4.35	1.15	
Heart Attack	4	2.99	1.34	
Stroke	0	0.72	0	
Respiratory Disease	1	0.72	1.39	
Cirrhosis	0	0.07	0	

TABLE 33: MORTALITY PATTERN AMONG ATLAS EMPLOYEES WITH AT LEAST 2 YEARS IN THE CONDITIONING DEPARTMENT

CAUSE OF DEATH	OBSERVED	EXPECTED	OBS/EXP	P
All Causes	51			
All Malignancies	19	14.4	1.32	
Respiratory				
Lung	7	5.09	1.37	
Larynx	0	0.21	0	
Digestive	5	4.37	1.14	
Esophagus	0	0.41	0	
Stomach	0	0.80	0	
Intestines/Rectum	4	1.77	2.26	
Pancreas	0	0.78	0	
Gallbladder	1	0.11	9.02	
Blood and Lymphatics	2	1.14	1.76	
Leukemia	1	0.46	2.17	
Multiple Myeloma	0	0.23	0	
Lymphoma	1	0.44	2.27	
Bladder	0	0.45	0	
Prostate	3	1.13	2.65	
Skin	1	0.19	5.26	
Brain	0	0.36	0	
Circulatory Disease	25	24.99	1.00	
Heart Attack	18	18.11	0.99	
Stroke	5	3.22	1.55	
Respiratory Disease	1	3.57	0.28	
Cirrhosis	2	1.00	2.0	

TABLE 34: MORTALITY PATTERN AMONG ATLAS EMPLOYEES WITH AT LEAST
2 YEARS IN THE FINISHING DEPARTMENT

CAUSE OF DEATH	OBSERVED	EXPECTED	OBS/EXP	P
All Causes	32			
All Malignancies	9	8.62	1.04	
Respiratory				
Lung	3	2.93	1.03	
Larynx	0	0.12	0	
Digestive	2	2.63	0.76	
Esophagus	0	0.23	0	
Stomach	1	0.48	2.08	
Intestines/Rectum	0	1.09	0	
Pancreas	1	0.46	2.17	
Gallbladder	1	0.11	9.02	
Blood and Lymphatics	2	0.69	2.89	
Leukemia	0	0.30	0	
Multiple Myeloma	2	0.14	14.53	
Lymphoma	0	0.28	0	
Bladder	1	0.31	3.20	
Prostate	1	0.83	1.21	
Skin	0	0.09	0	
Brain	0	0.18	0	
Circulatory Disease	18	16.06	1.12	
Heart Attack	13	11.37	1.14	
Stroke	3	2.26	1.33	
Respiratory Disease	0	2.57	0	
Cirrhosis	0	0.52	0	

TABLE 35: MORTALITY PATTERN AMONG ATLAS EMPLOYEES WITH AT LEAST 2 YEARS IN THE FORGE DEPARTMENT

CAUSE OF DEATH	OBSERVED	EXPECTED	OBS/EXP	P
All Causes	27			
All Malignancies	12	7.86	1.53	0.08
Respiratory				
Lung	3	2.80	1.07	
Larynx	0	0.11	0	
Digestive	4	2.35	1.70	
Esophagus	0	0.22	0	
Stomach	0	0.41	0	
Intestines/Rectum	2	0.94	2.12	
Pancreas	0	0.42	0	
Gallbladder	2	0.06	32.91	
Blood and Lymphatics	2	0.62	3.24	
Leukemia	0	0.25	0	
Multiple Myeloma	0	0.12	0	
Lymphoma	2	0.25	8.0	
Bladder	0	0.24	0	
Prostate	2	0.59	3.38	
Skin	0	0.11	0	
Brain	0	0.21	0	
Circulatory Disease	13	12.89	1.01	
Heart Attack	12	9.35	1.28	
Stroke	0	1.62	0	
Respiratory Disease	1	1.83	0.55	
Cirrhosis	0	0.56	0	

TABLE 36: MORTALITY PATTERN AMONG ATLAS EMPLOYEES WITH AT LEAST 2 YEARS IN THE ANNEALING DEPARTMENT

CAUSE OF DEATH	OBSERVED	EXPECTED	OBS/EXP	P
All Causes	23			
All Malignancies	13	6.28	2.07	<0.01
Respiratory				
Lung	3	2.17	1.38	
Larynx	0	0.09	0	
Digestive	6	1.90	3.16	<0.01
Esophagus	0	0.18	0	
Stomach	2	0.34	5.91	
Intestines/Rectum	3	0.79	3.78	
Pancreas	1	0.33	3.02	
Gallbladder	0	0.05	0	
Blood and Lymphatics	2	0.50	3.98	
Leukemia	0	0.21	0	
Multiple Myeloma	0	0.10	0	
Lymphoma	2	0.17	11.8	
Bladder	0	0.22	0	
Prostate	1	0.56	1.77	
Skin	0	0.07	0	
Brain	0	0.14	0	
Circulatory Disease	9	11.47	0.78	
Heart Attack	4	8.15	0.49	
Stroke	3	1.59	1.89	
Respiratory Disease	1	1.77	0.56	
Cirrhosis	0	0.40	0	

TABLE 37: MORTALITY PATTERN AMONG ATLAS EMPLOYEES WITH AT LEAST
2 YEARS IN THE INSPECTION DEPARTMENT

CAUSE OF DEATH	OBSERVED	EXPECTED	OBS/EXP	P
All Causes	36			
All Malignancies	10	10.3	0.97	
Respiratory				
Lung	2	3.67	0.55	
Larynx	1	0.16	6.44	
Digestive	3	3.09	0.97	
Esophagus	1	0.29	3.36	
Stomach	1	0.55	1.81	
Intestines/Rectum	0	1.26	0	
Pancreas	0	0.56	0	
Gallbladder	0	0.08	0	
Blood and Lymphatics	2	0.81	2.46	
Leukemia	0	0.33	0	
Multiple Myeloma	1	0.16	6.34	
Lymphoma	1	0.32	3.13	
Bladder	1	0.31	3.20	
Prostate	1	0.75	1.34	
Skin	0	0.13	0	
Brain	0	0.28	0	
Circulatory Disease	15	17.39	0.86	
Heart Attack	13	12.80	1.02	
Stroke	0	2.08	0	
Respiratory Disease	3	2.41	1.25	
Cirrhosis	1	0.83	1.20	

TABLE 38: MORTALITY PATTERN AMONG ATLAS EMPLOYEES WITH AT LEAST 2 YEARS IN THE ROLLING MILL

CAUSE OF DEATH	OBSERVED	EXPECTED	PMR	P
All Causes	31			
All Malignancies	6	8.55	0.70	
Respiratory				
Lung	3	2.99	1.00	
Larynx	0	0.12	0	
Digestive	1	2.60	0.39	
Esophagus	0	0.24	0	
Stomach	0	0.48	0	
Intestines/Rectum	0	1.07	0	
Pancreas	0	0.46	0	
Gallbladder	1	0.07	14.49	
Blood and Lymphatics	2	0.68	2.93	
Leukemia	1	0.28	3.55	
Multiple Myeloma	1	0.13	7.51	
Lymphoma	0	0.27	0	
Bladder	0	0.27	0	
Prostate	0	0.69	0	
Skin	0	0.10	0	
Brain	0	0.21	0	
Circulatory Disease	20	15.32	1.31	
Heart Attack	14	11.13	1.26	
Stroke	4	1.98	2.02	
Respiratory Disease	0	2.24	0	
Cirrhosis	2	0.64	3.11	

TABLE 39: MORTALITY PATTERN AMONG ATLAS EMPLOYEES WITH AT LEAST
2 YEARS IN THE SHEET MILL

CAUSE OF DEATH	OBSERVED	EXPECTED	OBS/EXP	P
All Causes	34			
All Malignancies	13	9.63	1.35	
Respiratory				
Lung	1	3.36	0.30	
Larynx	0	0.14	0	
Digestive	6	2.87	2.09	
Esophagus	1	0.27	3.69	
Stomach	2	0.51	3.94	
Intestines/Rectum	1	1.16	0.86	
Pancreas	1	0.52	1.93	
Gallbladder	1	0.07	14.30	
Blood and Lymphatics	3	0.79	3.79	
Leukemia	2	0.32	6.25	
Multiple Myeloma	0	0.15	0	
Lymphoma	1	0.32	3.08	
Bladder	1	0.29	3.45	
Prostate	0	0.73	0	
Skin	1	0.14	7.14	
Brain	0	0.27	0	
Circulatory Disease	11	16.09	0.68	
Heart Attack	7	11.69	0.60	
Stroke	2	2.02	0.99	
Respiratory Disease	8	2.32	3.45	
Cirrhosis	1	0.78	1.28	

TABLE 40: MORTALITY PATTERN AMONG ATLAS EMPLOYEES WITH AT LEAST 2 YEARS IN THE STRIP MILL

CAUSE OF DEATH	OBSERVED	EXPECTED	OBS/EXP	P
All Causes	26			
All Malignancies	6	7.40	0.81	
Respiratory				
Lung	3	2.64	1.14	
Larynx	1	0.11	8.82	
Digestive	2	2.24	0.89	
Esophagus	0	0.20	0	
Stomach	0	0.42	0	
Intestines/Rectum	1	0.91	1.10	
Pancreas	0	0.40	0	
Gallbladder	0	0.06	0	
Blood and Lymphatics	0	0.58	0	
Leukemia				
Multiple Myeloma				
Lymphoma				
Bladder	0	0.22	0	
Prostate	0	0.51	0	
Skin	0	0.10	0	
Brain	0	0.20	0	
Circulatory Disease	11	12.65	0.87	
Heart Attack	9	9.35	0.96	
Stroke	0	1.54	0	
Respiratory Disease	2	1.69	1.18	
Cirrhosis	0	0.60	0	

APPENDIX

DESCRIPTION OF THE ATLAS STEELS PLANT AND ITS HISTORY

This description has been abstracted from a pamphlet entitled Specialty Steelmaking at Atlas Steels Limited, written by T. J. Ess and first published in the April, 1959 edition of The Iron and Steel Engineer.

Atlas Steels operations were begun in 1928. The Company produces tool steels, high-speed steels, drill steels, special purpose steels, stainless steels, and construction steels. Its product mix includes billets, bars, strip, sheet, plate, wire, tubing and forgings. The plant is laid out in 2 principal units called the North Plant and the South Plant. The former includes the Melt Shop, bloom and billet mills, sheet mill, cold draw department, strip and tube mills, with their related finishing equipment, as well as the central maintenance shops. The South Plant consists of bar mills, finishing equipment, and some miscellaneous facilities.

The Furnaces

Steelmaking facilities at Atlas consist entirely of electric arc furnaces. The 2 small furnaces are top-charged, with the roofs being moved aside on gantry cranes and the scrap dropped into the furnace from buckets carried by overhead crane. The other 4 furnaces are door-charged by floor type charging machines. For tapping, the furnaces are tilted on toothed rockers.

Steel scrap of the proper analyses is charged into the furnaces, with 60-70 percent in the original charge and the remainder in a recharge after the original material has been partly melted down. The first slag is removed by tilting the furnace slightly and raking off slag through the furnace door, allowing it to fall through an opening in the floor to a slag pot below. The second, or reducing, slag is then formed by the addition of lime, fluorspar, sand, and fine coke or ferro-silicon. Steel is deoxidized by adding small quantities of aluminum or silicon.

The steel produced ranges through more than 200 grades of specialty products. Because of the wide range of analyses produced, extreme care is exercised in testing and segregating scrap for the electric furnaces. In the scrap yard there are alligator shears and oxy-acetylene facilities to cut up heavy scrap. A scrap baler is provided to form bundles of light scrap. Scrap is loaded by crane into railroad cars and moved to the melt shop, where it is transferred by magnet crane into charging pans or buckets. Crushing equipment is used to reduce silicon, tungsten, vanadium, titanium, etc. to the desired sizes. Alloys, fluxes, refractories, etc. are stored under the Melt Shop floor and brought up as needed by industrial trucks and overhead cranes.

Steel tapped from the arc furnaces may proceed in a number of courses. Prior to 1954, all steel was poured into hot-topped ingots. Still used regularly are square and corrugated rounds, and slab ingots. Early in 1954, Atlas began operation of a continuous casting machine. It is a vertical unit, with the casting floor 31 feet above ground and the discharge pit 20 feet deep.

Steel to be cast through this machine is tapped into bottom-pour ladles. The preheated ladle is filled with steel from an arc furnace, and is then moved by transfer car to the casting machine. An overhead crane lifts the ladle to the casting floor. As the ladle nozzle is opened, steel flows into a tundish, which acts as a reservoir, immediately above the mold. The liquid metal is at all times protected from oxidation with a propane atmosphere. The mold is made of pure copper with passages for cooling water.

At the start, a starting or dummy bar is inserted into the bottom of the mold. As molten steel flows from the tundish into the mold, it is chilled forming a shell. Pinch rolls act to pull down the starting bar, followed by the cast slab or billet. A vegetable oil is constantly injected to provide lubrication between mold and billet. As the billet moves lower, it passes through a series of small rollers which contain and support all sides. At the same time, water sprays speed up cooling.

Below this cooling chamber are 2 oxy-acetylene torches mounted so they clamp on the billet or slab and travel downward at the same speed as the billet while cutting is in progress. At the desired intervals, the torches go into action to cut the cast billets to the desired lengths.

The cut lengths are lowered onto a carrier which brings them back to a cooling bed at ground level. From the pickup cradle, the billets or slabs may be moved to reheating furnaces at the rolling mills.

A new Melt Shop was constructed after this article was written, and it came into production in 1976.

The Blooming Mill

Most of the steel from the Melt Shop, whether cast into ingots or through the continuous casting machine, is rolled through the blooming mill.

Steel is first reheated in 12 soaking pits, which are end-fired with natural gas or fuel oil. Steel is charged into the pits and drawn from them with cranes; ingots and cast slabs are carried to the mill approach table by a self-propelled ingot buggy. Products from the mill are blooms and slabs. In line with the mill is an automatic scarfing machine which can desurface all four sides of blooms or slabs. After cooling, the scarfed slabs and blooms are put through a shot blast unit to remove scale and slag resulting from the scarfing machine.

Billet Mill

A cross-transfer immediately following the blooming mill connects with a line which reduces the blooms down to billet sizes. Steel from the mill may be cut to lengths by shear, hot saw, or torch. The products are then cooled, after which the material is moved to the billet conditioning department or annealing department.

Conditioning Department (includes Chipping and Grinding, Annealing)

The conditioning department contains facilities for chipping low grade alloy grades and for grinding stainless and high alloy grades. There are also 3 batch tanks where some products are pickled before conditioning. Annealing facilities here include 8 car type annealing furnaces, 6 pit furnaces and 2 continuous furnaces. Two hydraulic straighteners can process billets and blooms, and there are also hacksaws and an automatic cut-off.

Forging Departments

In one department, adjacent to the Melt Shop, are a 1200 ton press and a 6 ton hammer. Both are used for reducing ingots and finished forging work. The other forging Department, located in the South Plant contains 6 air operated hammers.

Bar and Rod Mills

To produce smaller sizes, Atlas has 2 bar mills. Number 1 mill rolls rounds, squares, flats, hexagons, octagons, and some special shapes. This mill is used to roll bars of the lower alloy grades and coils of all grades. Number 2 mill is a jobbing unit which receives billets and reduces them to bar sections. This mill is used mainly for bars of the higher alloy grades.

Convenient to the mills at the South Plant are additional finishing facilities designed to handle the products from the bar mills and the forge. Heat-treating and annealing are performed in oil-fired and electric furnaces. The South Plant finishing Department also contains an extensive layout of straightening equipment.

Cold Draw Department

The cold draw Department is located in a separate building

at the north end of the plant. The department receives hot-rolled annealed bars and coils from the mills. To remove all surface scale, material is next pickled in batch acid tanks. Bars and coils are then washed and immersed in a hot suspension of lime which neutralizes any remaining pickling solution, retards rusting, and aids lubrication during the draw.

Bars are drawn on a draw bench to the appropriate diameters.

Strip Mill

Atlas installed a hot and cold strip mill in 1954. Stainless slabs from the blooming mill are reduced by as much as 95% on a single pass through the mill. Following reduction, the strip passes to a coiler. Some slabs are reduced only to about 1" in thickness, then cut up into sheet bar for further rolling in the hot sheet mill.

Hot rolled product from the sheet mill is normally flattened, edge-trimmed, and recoiled. It is next taken to 2 annealing and pickling lines located in the end of the hot mill building. These lines each contain uncoilers, welder, looping pit, annealing furnace, quenching unit, salt descaling unit, washer, acid tanks, scrubber and dryer, inspection bench, shear, and recoilers.

Unless destined to be sold as hot rolled, pickled material, the coils are cold rolled. Strip can be reduced in a number of passes by as much as 90%. Each pass, however, hardens the steel, and in rolling thin gauges, it is generally necessary to return coils to the annealing-pickling lines for intermediate annealing.

Tube Mill

Material to be made into tubes comes in coils accurately slit to width on the cold slitting line. The mill forms the strip until its edges meet and the seam closed. An automatic electric arc welding machine joins the edges under a blanket of helium. No welding rod is used. Small tubes are degreased in trichloroethylene, and given a bright anneal in an atmosphere of cracked ammonia. Large tubes are handled in the same way except that they are annealed in a large conventional furnace and then pickled.

Sheet Mill

In 1950 equipment was installed for the production of stainless steel sheet and plate. Hot rolled product is annealed and racked up for pickling. Pickling is performed in a series of batch operations. First is a dip in molten sodium hydroxide, next a water quench, immersion in heated sulfuric acid, a water

rinse, immersion in heated nitric-hydrofluoric acid, rinsing and washing, scrubbing and drying. A cold mill performs the cold reduction after which, the product is again annealed and pickled.

The sheet mill produces sheet and plate in a number of grades as well as some super alloys, tool steels, and titanium and zirconium alloys.

Quality Control

To insure a high degree of quality, the chemical, metallurgical and inspection departments act as watch-dogs at all important steps in the process.

An important function of the chemical laboratory is routine melting furnace control to help the melter hit the desired analysis. The laboratory also checks the composition of incoming scrap, and checks analyses of billet samples to confirm ladle analyses.

Through a staff of metallurgists, observers, and technicians, the metallurgical department scrutinizes all phases of plant operation. A central laboratory evaluates each heat of steel before it proceeds into production. Special laboratories are set up at the cold draw and strip and tube departments.

The inspection department is primarily concerned with the physical aspects of quality, such as dimensions, shape, surface etc. Its activities centre around the conditioning department, cold draw department, sheet mill, strip and tube mill, and at the South Plant where all rolled and forged bars, forgings, rings, disks, and die blocks pass.

Maintenance

Maintenance is carried on by millwrights, electricians, pipefitters, and oilers assigned to the operating units. Major repairs and shopwork are performed by centralized crews of skilled tradesmen. The central maintenance building houses carpenter, pipe, millwright, electric, rigger, welding, paint, bricklayer, and instrument repair shops.

Transportation

Transportation within the plant is carried on by rail and truck. Three diesel locomotives operate on 6 miles of track. A fireless locomotive operates on the melt floor.